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Report

A Visual Description of the Concrete Exterior of the Cactus Crater Containment Structure

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Disclaimer

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Cover photo: View from atop of the Runit Island Radioactive Waste Containment Structure overlooking the Lacrosse nuclear test crater (40 kt, 05/04/1956 - DOE/NV-209-REV 15) (Photo Credit: Terry Hamilton, May 2013).

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A Visual Description of the Concrete Exterior of the Cactus Crater Containment Structure

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- During the Radiological Cleanup of Enewetak Atoll (1972-1980), radioactively contaminated soil was removed by excision and buried inside the Cactus nuclear test crater on Runit Island.
- The stabilized debris pile, consisting mostly of a soil-cement grout mixture with some encapsulated oversize soil and debris, structural steel and concrete, was subsequently covered over with a 45 centimeter thick, non-load-bearing layer or cap of concrete to protect the waste mound from natural erosion.
- The Cactus crater containment structure is commonly known as "*Runit Dome*".
- The 1986 Compact of Free Association (COFA) (P.L. No. 99-239 Stat 1770) between the United States and the Republic of the Marshall Islands provides for a "full settlement of all claims, past, present and future" related to the U.S. nuclear test program in the Marshall Islands.
- P.L. 112-149 was developed to provide U.S. legislative authority outside of COFA and the U.S. Department of Energy's Marshall Islands Program to address radiological concerns about leakage of radioactive waste from *Runit Dome* into the environment. The intent of the P.L. is to support efforts to conduct periodic visual surveys of Runit Dome and implement a groundwater monitoring program on Runit Island. Findings from these studies are expected to provide a basis for quantifying the risk posed by leakage of radioactive waste from *Runit Dome* on the long-term health status of the people of Enewetak.
- The radiologic inventory buried beneath *Runit Dome* is dwarfed by the current inventory of fallout radionuclides in atoll lagoon sediments. Consequently, catastrophic failure of the concrete dome façade covering the debris mound and instantaneous release of all its contents into the lagoon will not necessarily lead to any significant change in the radiation dose delivered to the local resident population. However, current findings confirm there is a rapid tidal response in the height of groundwater beneath the containment structure. Therefore, under a more plausible release scenario, the potential does exist for contaminated groundwater from *Runit Dome* to flow into the nearby, subsurface marine environment. Similarly, uncertainties do remain about the total inventory and isotopic mix of fallout radionuclides contained in, and on the nature, integrity and potential to mobilize radionuclides from, the aged waste pile.

- Any contaminated groundwater from beneath *Runit Dome* that reaches outflow points in the lagoon or on the ocean reef will be very rapidly diluted. Under this scenario, there will likely be little or no measureable or discernible increase in the radiation burden delivered to marine biota or the local human population on Enewetak. As such, historical studies have generally been dismissive about possible hazards associated with *Runit Dome* by use of a simple inventory argument and the rapid turnover time of sea water inside the lagoon. Such arguments have failed to alleviate the concerns of the people of Enewetak and its leadership.

- The groundwater monitoring program conducted under P.L. 112–149 is intended to support the development of a conceptual model of groundwater flow and mass-transport of radionuclides from *Runit Dome* under different release scenarios. The initial phase of the project will focus on developing baseline measurement data on the time-evolution of water quality in the near-field, subsurface environment around *Runit Dome*. This high-resolution, contemporary measurement data will also be used to study the impact of forcing events such as tidal surges and storms on groundwater flow and mass-transport of radionuclides. These data and information are keys to providing understanding and interpretation of any long-term trends in groundwater quality inside and around *Runit Dome*. In this way, the groundwater monitoring program will support the development of a full and comprehensive assessment of the potential health and ecological impacts of any leakage of radioactive waste from *Runit Dome*, without relying on simple inventory arguments based upon the remobilization of radionuclides contained in lagoon sediments. In a very simplistic way, the groundwater monitoring program implemented under P.L. 112–149 could be viewed and presented publically as an 'early warning' system to assess significant changes in water quality before any radioactive material necessarily leaves the site boundary. As such, the groundwater monitoring program in and around Runit Dome will support U.S. agency efforts to address the concerns of the Enewetak community in a more direct and definitive manner, and help build public confidence in the maintenance of a safe and sustainable resettlement program.

- If the Cactus crater concrete containment structure on Runit Island were located in the United States proper (or subjected to U.S. regulatory authority), it would be formally classified as a Low-Level Radioactive Waste Disposal Site and be subject to stringent site management and monitoring practices. A long-term groundwater monitoring program would almost certainly form an integral part of these activities.

- The current visual survey took place between 29 May and 5 June of 2013 in partial fulfilment of clause (B)(i)(I) of the P.L. to perform a visual study of the concrete exterior of the Cactus crater concrete containment structure on Runit Island.

- The concrete cap covering *Runit Dome* appears to be structurally sound in providing an effective and erosion resistant crypt to seal off the radioactive material below.

- Some visually-defective elements were identified during the visual survey, including cracks and spalls in the concrete cap, and recommendations put forward for their repair. These actions are considered essential for two key reasons;

(i) To reduce the potential for rainwater infiltration down through the cracks in the dome and possibly influencing groundwater flow and radionuclide migration into the subsurface, marine environment; and

(ii) To alleviate negative public perception that the overall effectiveness of the structure is compromised and allowing potentially harmful quantities of radioactivity becoming available for human exposure.

- It is only after drilling a suitable network of groundwater sampling wells that a work program can be devised and implemented to meet the intent of P.L. 112-149 in a scientifically meaningful and defensible manner.

- In the interim, the environmental and human monitoring programs supported by the U.S. DOE should be continued to ensure that the people of Enewetak are being adequately protected from all possible routes of radiation exposure, including that associated with leakage of radioactive waste from *Runit Dome*.

SCOPE

This work was performed under the auspices of the U.S. Department of Energy (DOE) by Lawrence Livermore National Laboratory (LLNL) in support of Public Law (P.L.) 112–149 as cited under the Insular Areas Act of 2011 and amended in Section 103(f)(1) of the Compact of Free Association Amendments Act of 2003 [48 U.S.C. 1921b(f)(1)]. The relevant section of the P.L. appears under the title 'SEC 2 Continued Monitoring of Runit Island', clause (B)(i) Cactus Crater Containment and Ground Water Monitoring, part (I) a visual study of the concrete exterior of the Cactus Crater radioactive waste containment structure on Runit Island.

BACKGROUND

Between 1948 and 1958, the United States (U.S.) conducted 43 atmospheric nuclear weapons tests at Enewetak Atoll in the northern Marshall Islands. Prior to commencement of the test program, the 150 or so residents living on Enewetak Atoll were relocated to Ujelang, a small unpopulated atoll located about 250 kilometers to the SW of Enewetak. The vast majority of the nuclear tests detonated on Enewetak were conducted in the northeastern quadrant of the atoll, leaving the southern islands relatively free of contamination. Surface detonations over land led to localized fallout contamination of islands with significant quantities of unfissioned nuclear fuel along with varying quantities of fission and activation products. Other legacy materials abandoned during the course of the nuclear test program included scrap metal debris, concrete, cables, bunkers, excess equipment and other miscellaneous materials, radiological or otherwise.

The pace of the U.S. nuclear weapons testing program quickened in the months leading up to the introduction of the U.S. test moratorium on 31 October of 1958. Between April and August of 1958, a total of thirty three nuclear tests were conducted in the Marshall Islands under Operation HARDTRACK I (DOE, 2000). The last two nuclear test events, code named Quince and Fig, were detonated on the surface of Runit Island on Enewetak Atoll (DOE 2000). Radiological surveys would later reveal that particles recovered from the vicinity of the Quince and Fig ground zero contained relatively high concentrations of plutonium-239 (^{239}Pu), including fragment size particles (DOE, 1982). This region of Runit Island–most commonly known as Fig-Quince–would become a major focus area during the cleanup and rehabilitation program (DNA, 1981) and, in many respects, still remains a nuclear legacy issue of concern today.

Between 1958 and 1976, Enewetak Atoll continued to be used for various U.S. Department of Defense (DoD) programs up until the start of cleanup program in May 1977 (Davisson and Hamilton, 2008; DOE, 1982). During the 1960s, Enewetak Atoll was a primary target location for testing of Intercontinental Ballistic Missiles, and would later be used for test firings of a development High Energy Upper Stage (HEUS) rocket motor. Two test firings of the rocket motor were performed on Enjebi Island. Each motor containing up to 1130 kilograms of propellant, including a significant quantity (~134 kilograms) of beryllium. During 1972-74, Enewetak Atoll was also used to support the U.S. Air Force (USAF) led Pacific Cratering Experiment (PACE) program. The aim of PACE was to use very large conventional explosive charges to provide ground motion calibration data, verify data acquisition systems for detection and study the environmental impacts, of low-yield nuclear detonations. The PACE 2 program would ultimately be re-structured and renamed Exploratory Program on Enewetak (EXPOE) after the people of Enewetak filed a court order to halt activities performed under the initial PACE program. The drill holes and test wells developed under PACE and EXPOE would prove to be valuable assets for later research conducted on coral atoll groundwater hydrology and radionuclide dispersion. It may also be possible to use some of these existing wells under the current groundwater monitoring program on Runit Island.

Also concurrently, since its establishment in 1954 through until after completion of the Enewetak cleanup program, the Enewetak Marine Biological Laboratory (EMBL), operated by the University of Hawaii under the auspices of the Division of Biology and Medicine of the U.S. Atomic Energy Commission (AEC), maintained a presence on Enewetak and developed an extensive research program in coral atoll ecology. The laboratory was re-named the Mid-Pacific Marine Laboratory (MPML) in 1974 and then, in 1979, the name of the laboratory was again changed to the Mid-Pacific Research Laboratory (MPRL) to more actually reflect the broadening scope of research work being conducted on and around the atoll.

The Enewetak Atoll use agreement obligated the U.S. to review their needs for the islands every five years. Through the early 1970s, U.S. operations on Enewetak Atoll were already in serious decline. In 1972, a decision was made to return Enewetak Atoll to the Trust Territory of the Pacific Islands (TTPI) for subsequent return to the people of Enewetak. This announcement committed the United States Government (USG) to the survey, cleanup and rehabilitation of Enewetak Atoll. Planning for the project extended between 1972 and 1977, and involved several concurrent activities. In 1972, an interagency conference was held to decide on possible cleanup options, and concluded that the cleanup and rehabilitation methods used on Bikini Atoll would also be applicable to Enewetak Atoll (Davisson and Hamilton, 2008). During the same year, the AEC commenced a preliminary radiological survey of Enewetak Atoll.

The radiological cleanup of Enewetak Atoll was primarily directed towards reducing levels of plutonium contamination in surface soils. Justification for this approach was based on the notion that plutonium has very long half-life, and offered the greatest potential for long-term exposure of the resettled population from ingestion or from inhalation through resuspension (DNA, 1980). The cleanup program also included provisions for disposal of non-radioactive debris such scrap metal, concrete and excess equipment. Judgments and priority rules for the Enewetak cleanup program were initially based on discussions between the DNA, the AEC/Energy Research and Development Administration (ERDA), and a Task Group of interagency experts. With the advent of the U.S. DOE, an Advisory Group on the cleanup of Enewetak was formulated in 1978, providing more specific recommendations to the DNA and DOE on applicable cleanup criteria and associated recommendations. Under this management accord, the Nevada Operations Office at the U.S. DOE was assigned continuing responsibility for the radiological characterization of the atoll and for certification of radiological conditions on each island after completion of the project. The general consensus conditions for cleanup of Enewetak were predicated around removing soil that exceeded 14.8 Bq of plutonium per gram of soil, removing or amending soil containing between 1.48 and 14.8 Bq of plutonium per gram of soil, and disposing and stabilizing the accumulated waste in an unlined nuclear test crater on Runit Island (DNA, 1981; DOE, 1982). Different positions held during various meetings and in cited testimony during the course of the cleanup program indicate that priority decisions on island cleanup were dynamic in nature. Decisions were made on a case-by-case basis with consideration given to the level of soil contamination and anticipated land-use patterns for various islands, along with other operational factors such as boat access and the volume of contaminated soil and debris present (DNA, 1981; DOE, 1982). During the course of the cleanup program, it was generally agreed that the cleanup criteria developed for plutonium should apply to the sum of transuranium (TRU) elements, where the TRU activity is the sum of the plutonium isotope [plutonium-238 (^{238}Pu), plutonium-239 (^{239}Pu) and plutonium-240 (^{240}Pu)] and americium-241 (^{241}Am) activity concentration in soil.

Over 4,000 U.S. servicemen assisted in the cleanup operations, with six lives lost, in what became known as the Enewetak Radiological Support Project (DNA, 1981; DOE, 1982). An estimated 83,000 cubic meters of contaminated surface soil were identified and removed by excision – the stripping of successive layers of soil using earth-moving equipment – and disposed of inside the Cactus nuclear test crater on the lagoon side of the ocean reef on the north end of Runit Island (DNA, 1981). An additional 4,700 cubic meters of radiologically contaminated debris was also identified, transported to Runit Island, and immobilized in concrete inside the crater. From the outset of the cleanup program, it was clear that the dri-Enewetak people could return safely to the island of Enewetak in the south. It was also hoped that the dri-Enjebi people could return to their home island in the north. However, upon analyzing the results of the radiological survey, the AEC decided that residual levels of fission products, namely cesium-137 (^{137}Cs), in Enjebi Island soil was such that people eating locally grown tree-crop foods could acquire higher than acceptable lifetime body burdens of radionuclides. Accordingly, the Master Plan developed by the AEC in conjunction with the people of Enewetak, called for the dri-Enewetak and dri-Enjebi people to reside together on Enewetak, Medren and Japtan islands in the south (DNA, 1980).

Cactus crater was formed on 5 May 1958 as a result of the 18-kiloton Cactus test shot conducted under Operation HARDTACK (DOE, 2000) (Fig. 1). The original crater measured about 106 meters in diameter, and had a maximum depth of about 9.5 meters below the Approximate Mean Low-Water Spring tide (AMLWS), not including the depth of pulverized fallback material contained in the bottom of the crater (Ristvet, 1978). Under the Enewetak Radiological Support Project, the crater and stabilized waste mound were covered over by a circular, dome shaped concrete façade or cap to provide an erosion resistant crypt to seal off the radioactive material below (Fig. 2). Planning and cleanup operations are described in detail in a DNA report (DNA, 1981) and are summarized in a DNA Fact Sheet (DNA, 1980). In addition to disposal of radioactive soil and debris inside Cactus crater, about 170,000 cubic meters of uncontaminated debris was removed from island and reef areas and disposed of at designated dump sites in the lagoon and in shoreline protection (DNA, 1980). Also, about 16,000 items of World War II ordinance, such as unexploded artillery projectiles, mortar shells, hand grenades, and small arms ammunition, were identified, dug up and disposed of by Navy Explosive Ordinance Disposal Teams (DNA, 1980). At the completion of the radiological cleanup of Enewetak Atoll, thirty islands on Enewetak Atoll were designated as meeting the TRU cleanup standards for residential and subsistence agricultural use, seven qualified as agricultural islands, and two qualified as food gathering islands (DNA, 1980). Runit Island was simply identified as having high-level TRU contamination removed.

Fig 1. Post-shot view of the nuclear test crater formed by the 18-kt Cactus test conducted on the north end of Runit Island, Enewetak Atoll.

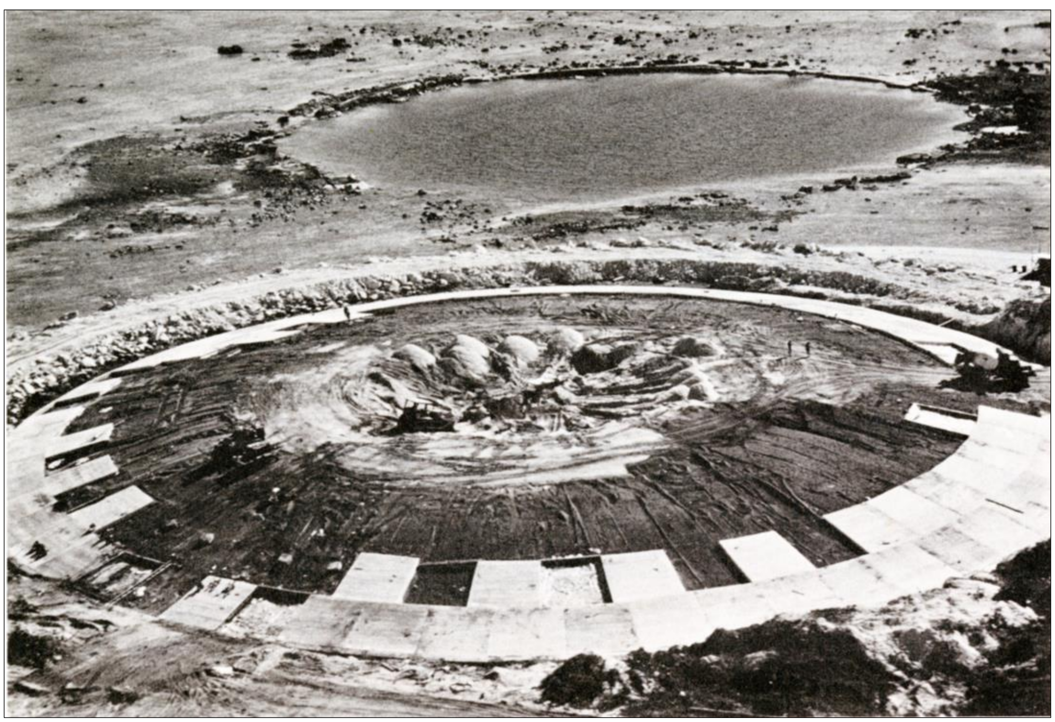

Fig 2. View of the Cactus crater containment structure during construction of individually formed concrete panels [The Lacrosse crater can be seen in the background].

Construction on the Cactus crater concrete containment structure was completed in 1979. The structure consists of three basic design elements as shown schematically in Fig. 3. The design elements consist of:

i. A keywall designed to prevent scouring and undercutting of the containment structure. The keywall has a circumference of 363 meters and contains 99 individually poured concrete sections. The keywall sections were designed to be 0.62 meter thick, and rest on 'competent bedrock' or be a minimum of 2.5 meters (8 feet) high (Ristvet, 1980; DNA, 1981).
ii. A waste pile consisting of;
    a. A mixture of contaminated soil, Type II Portland cement and attapulgite (a colloidal suspending agent) placed inside the crater below high-tide level using a concrete pump and tremie operation of underwater concrete placement;
    b. Encapsulated oversize soil and debris, structural steel, and concrete placed inside the crater by dumping and bulldozing;
    c. Contaminated soil and in excess of four hundred bags of higher-grade waste, including Pu contaminated fragments from the Fig-Quince zone on Runit Island, placed in the top center of the mound (an area known as the "Donut Hole") and choked with clean concrete slurry; and;
    d. Contaminated soil placed inside the crater above high-tide level in a soil-cement operation. The soil-cement operation involved spreading out layers of dumped soil using a grader, and mixing the soil with dry cement using a disc harrow. Water was then added, and the material compacted into a consolidated soil-cement grout mixture using a vibrating roller.
iii. A non-load-bearing layer (cap) of concrete to protect the mound of contaminated material below from natural erosion. The concrete cap is composed of 357 individually formed, trapezoidal shaped, concrete panels and a top section. Each panel was poured to a design thickness of 45 centimeters (DNA, 1981). The individual panels vary in size from 6.2 x 6.5 meters around the shirt of the dome to about 1.85 x 2.3 meters near the apex. The panels are arranged in eleven circular ring rows, labeled in sequential order from A through K up from the base of the dome. The center cap section is designed as the L segment. Individual panels within each ring row also carry unique numeric identification numbers, e.g., C-1, C-2, C-3, etc. Panel identification labels are engraved in the lower, left corner of each panel but do not consistently start at the same orientation between each ring row. There are also several instances where the identification label is either not visible (missing) or the number sequence assigned to a particular panel within a ring row has been skipped or duplicated. The concrete cap was constructed without adding any internal reinforcing or expansion joints between individual panels. The one exception was an asphalt impregnated expansion joint placed between the first ring row and the keywall (DNA, 1981).

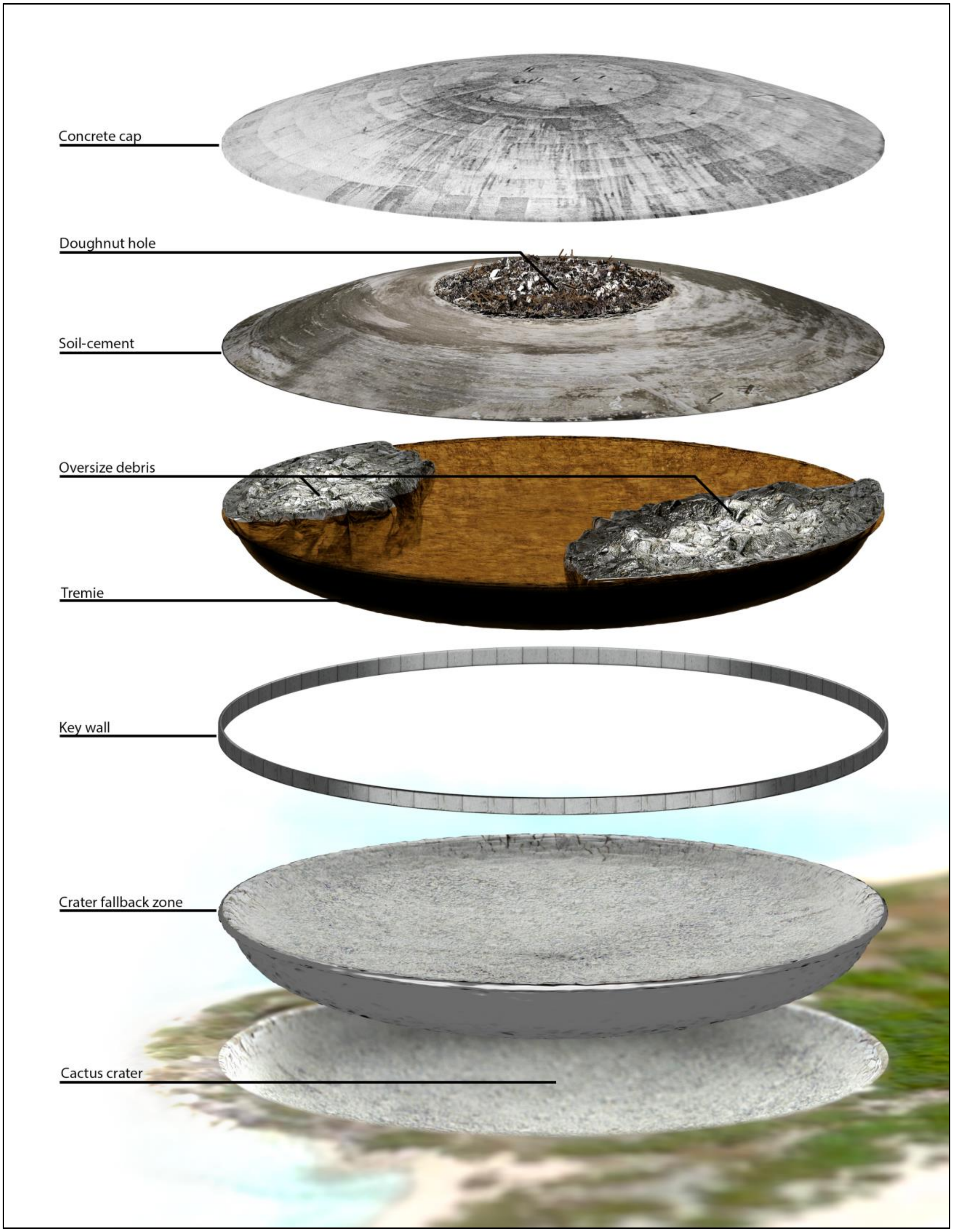

Fig. 3. Generalized schematic showing the layout and various design features of the Cactus crater containment structure.

The Cactus crater containment structure has a mean radius of approximately 57 meters and an apex standing about 7.4 meters above the surrounding keywall (this study). The structure is protected by an artificial riprap 'mole wall', or revetment, located along the ocean reef side of the keywall. The riprap wall was constructed of large size quarry blast rock and rejected keywall concrete sections, and choked with smaller rocks and aggregate (DNA, 1981). The top and sides of the riprap wall are overgrown with vegetation including small shrubs (mostly *Scaevola taccada*) and vines (*Ipomoea macrantha*) (Fig. 4a&b). Remnants of the original crater wall are still visible on the island side of the containment structure closest to the ocean reef.

It should be noted that the land and vegetation established between the containment structure and the lagoon were inundated by a high-tide storm event in 2009. The storm surge opened up a sandy channel extending up from the ocean reef towards the containment structure, depositing coralline sand and vegetative debris over the bottom panels on the western side of the dome (Fig. 5). The storm surge also filled in one of two historical groundwater sampling drill holes on land adjacent to the containment structure.

The Cactus crater containment structure on Runit Island has always been a great concern to the people of Enewetak because of the potential health and ecological risk posed by possible leakage of radioactive waste into the environment. At the time of cleanup, it was estimated that the TRU inventory of contaminated soil dumped inside Cactus crater was approximately 545 GBq (NDA, 1981). Noshkin et al., (1980) estimated that the amount of contaminated soil dumped inside Cactus crater represents about 0.8 percent of the total TRU inventory found in Enewetak lagoon sediment. This estimate may even be much lower because of the effects of burrowing infauna on the vertical distribution of fallout radionuclides in atoll lagoon sediments (McMurtry et al., 1986; Sushanek et al., 1986). Approximately half (278 GBq) the TRU inventory contained in the debris pile was contaminated soil originating from 5 islands to the north. The remaining material (267 GBq) was higher-grade contaminated soil and radioactive debris from Runit Island that was dumped above ground in the “Donut Hole” as previously described.

In general, the radiological cleanup of Enewetak Atoll (1972-1980) was a declared success in terms of removing overt environmental hazards from the atoll, radiological or otherwise; reducing the level of plutonium in surface soils to prescribed cleanup standards; and by placing the waste soil and debris in isolation in the form of a soil-cement grout mixture inside Cactus crater. An investigation by the Army Chief of Engineers indicated that there were some deviations from the original Pacific Ocean Division (POD) design, and some other noted deficiencies in the overall construction of the containment structure but, at the same time, concluded that the structure was sufficiently stable to achieve the design intent (POD-COE, 1980). In March 1980, an independent study was carried out by the National Academy of Sciences (NAS) at the request of the Director of DNA. The specific aims of this investigation were to assess effectiveness of the containment structure to prevent harmful quantities of radioactivity from becoming available for human exposure, and to recommend whether the assessment should be reviewed at intervals in the future (DIRDNA, 1980). Based on analysis of core samples, the NAS study showed that the concrete cap covered the containment structure was of high quality but there were some noted deficiencies in the keywall and tremie that could potentially impact the durability of the structure (DNA, 1981). These deficiencies, however, did not give reason for the NAS to condemn the use

Fig. 4a. Vegetation growing on the inside of the riprap 'mole wall' surrounding the Cactus crater containment structure on Runit Island (Visual Survey, May 2013).

Fig. 4b. View of ripwall 'mole wall' from the ocean reef (concrete blocks in the foreground are unrelated to the riprap wall) [Visual Survey, May 2013].

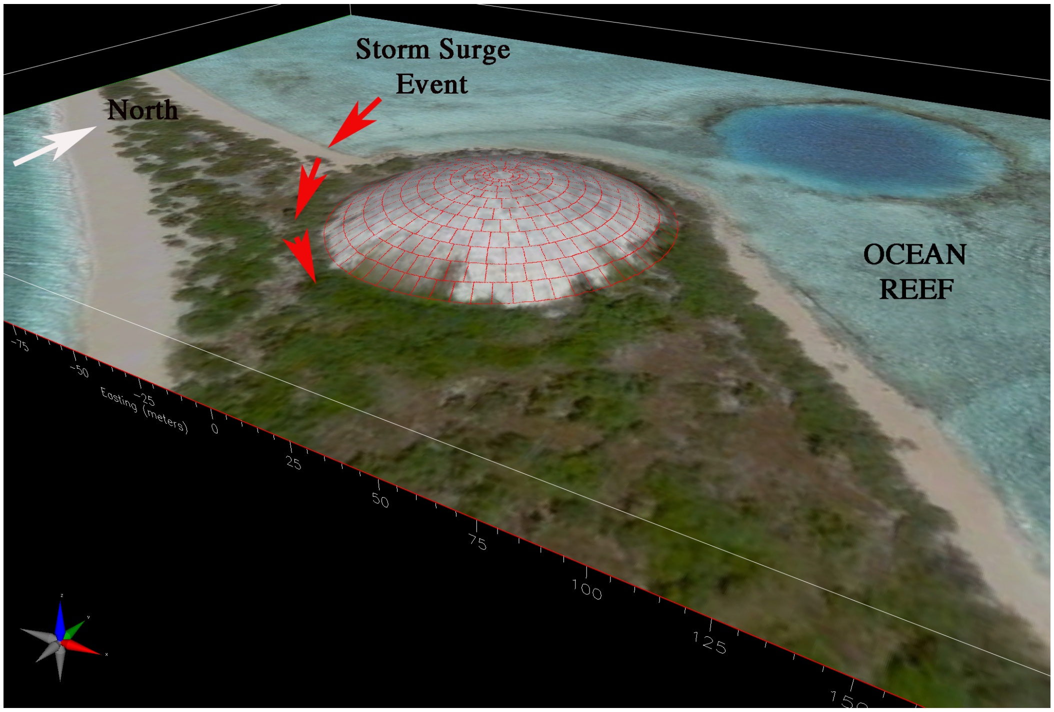

Fig. 5. A Google image of the Cactus crater containment structure on Runit Island showing a schematic overlay of the concrete panels (in red) [The red arrow depicts the flow of sea water from the 2009 storm surge event that impacted the landscape on the western fringe of the dome].

of the containment structure neither for its intended purpose nor to express significant concern about the possibility of radioactive contaminants from beneath the dome becoming available for internal or external human exposure. At this time, it was the decision of the DNA, the U.S. DOE, high-chief (Iroij) Johannes Peter and the people of Enewetak to place Runit Island under an indefinite quarantine (DNA, 1981). This was done not because of concern about exposure to waste materials inside the Cactus crater containment structure but because of the possibility that wave or storm action over other parts of the island could expose subsurface soils containing Pu concentrations in excess of the U.S. DOE guidelines for cleanup. It was the consensus of all concerned that the people of Enewetak Atoll should consider Runit Island to be strictly 'off limits'.

Continuing United States responsibilities under the United Nations' Trusteeship of the Marshall Islands contained a requirement for the DNA to monitor the Cactus crater containment structure. A Memorandum of Agreement (MOU) was henceforth established in 1981 between the U.S. DOE Nevada Operations/Pacific Area Site Office (NVO/PASO) and the DNA to provide services of U.S. DOE contractors to conduct visual surveys of the concrete containment structure. This monitoring effort was only directed at observation of the containment structure and to provide such data, without interpretation, that could be 'utilized by reviewing personnel to ascertain whether or not the dome continues to maintain its structural integrity'. The first visual inspection was carried out in June of 1982 by Holmes & Narver (H&N) in cooperation with University of Hawaii personnel stationed at Enewetak. U.S. DOE contractors also assisted with erecting no trespassing signs prohibiting visitors to the island. A subsequent survey was conducted in December of 1982 soon after Typhoon Pamela had passed through the area (H&N, 1983a).

A thorough search of historical record holdings held at the Nuclear Testing Archive (NTA)/National Security Technologies LLC (NSTec) for this period reveals that visual surveys of the containment structure, and the associated shoreline, were carried out in June 1983 (H&N, 1983b) and January 1984 (H&H, 1984). A copy of the initial 1982 survey report appears to be missing from the archive.

In 1986, under the Compact of Free Association Act (P.L. 99-239), the Government of the Republic of the Marshall Islands (GRMI) agreed to espouse what had been hitherto United States' duties and responsibilities, through the DNA, for monitoring of the containment structure. However, the U.S. Department of Interior (DOI) through the TTPI continued to provide annual funding to NV/PASO to assist in the successful resettlement of the *dri-Enewetak* people on their home atoll. Resettlement support activities included such functions as helping the motor-sailer, *WETAK-II*, supplemental food program, billeting of U.S. school-teachers, and the repair and maintenance of Enewetakese' housing units. Support was also extended to maintaining of the "no trespassing" signage on Runit Island.[1]

Under the 1986 COFA Act, DNA requirements and funding support to DOE to conduct visual surveys of the Cactus crater containment structure came to abrupt halt. However, the TTPI funded NVO/PASO support mechanism on Enewetak afforded opportunity for DOE contractors to provide 'ex gratia' help, initially under direction of NVO/PASO Director, Mr. Joseph Dryden, and continue to perform periodic surveys of the containment structure. One such engineering and photographic survey was thought to include an assessment of gamma radiation exposure rates around the dome (W. Jackson, per. comm.). Based on information gathered from available NTA holdings, it appears that additional photographic surveys of the containment structure were conducted during 1988 (copy unavailable), August of 1989 (H&N, 1989) and July of 1990 (RSN, 1990).

In late 1991, DOE management responsibilities in the Marshall Islands were transferred over from the Office of Defense Programs (DP) to the Office of Environment, Safety and Health (EH). A decision by EH Director at that time to close the Enewetak Field Station led to an abrupt end to many U.S. DOE contractor resettlement support functions on Enewetak, including efforts to survey the Cactus crater containment structure on Runit Island.

Over the next decade, U.S. DOE contractor support on Enewetak was largely directed towards grid sampling and radiological characterization studies of the northern islands under the continuing LLNL environmental program. In addition, scientists from the Brookhaven National Laboratory (BNL) conducted periodic missions to Enewetak to monitor the local population for internally deposited fallout radionuclides using whole body counting and Pu bioassay. LLNL assumed full responsibilities for the environmental and human radiological monitoring activities on Enewetak Atoll in 1998. At that time, the U.S. DOE did not have a legal mandate or the funding resources to initiate a long-term monitoring program on Runit Island but was able to establish a framework for cooperation between the parties. A formal task plan with shared levels of responsibility was developed in August 2000 under a 5-year MOU agreement between the U.S. DOE, the GRMI, and the Enewetak-Ujelang Local Government (EULGOV) (MOU, 2000). The action plan called for the construction of a permanent radiological support facility on

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[1] It should be noted that while U.S. DOE contractors remind the local population living on Enewetak Atoll not to use Runit Island, the USG has no formal enforcement responsibilities for maintaining the quarantine status of the island.

Enewetak Island and then, amongst other initiatives, to implement a comprehensive, radiological protection monitoring program for the local resident population. Construction of the Enewetak Radiological Laboratory (Fig. 6) was completed in March of 2001. This facility houses a whole body counter and provides clean living space for collection of bioassay urinalysis samples (Bell et al., 2001). The last visual survey of the Cactus crater containment structure was conducted during August of 2008 (NSTec, 2008).

Most importantly, the radiological protection-monitoring program implemented under this cooperative MOU agreement provides an accurate and reliable basis for assessing levels of internally deposited fallout radionuclides incorporated into peoples' bodies from all possible exposure pathways. This includes possible intakes from the consumption of radioactively contaminated fish and other marine biota caught in close proximity to the containment structure. In general, results stemming from this human monitoring program over the past decade clearly show that the dose contribution from internally deposited fallout radionuclides, such as ^{137}Cs and Pu, is not placing the resident population on Enewetak Atoll at any significantly elevated health risk.

The radiologic inventory beneath the Cactus crater containment structure is dwarfed by the current inventory of fallout radionuclides in atoll lagoon sediments (Noshkin and Robison, 1997; Davisson et al., 2012). Consequently, catastrophic failure of the concrete façade covering the debris pile and instantaneous release of all its contents into the lagoon will not necessarily lead to any significant change in the radiation dose delivered to the local resident population. However, current findings confirm there is a rapid tidal response in the vertical height of groundwater beneath the containment structure. Therefore, under a more plausible release scenario, the potential does exist for contaminated

Fig. 6. The Enewetak Radiological Laboratory.

groundwater from beneath the containment structure to flow into the near-field, subsurface marine environment, and possibly form more localized contamination regimes in and around outflow points in the lagoon or on the ocean reef. Similarly, uncertainties do remain about the present-day, total inventory and isotopic mix of fallout radionuclides contained in, and on the nature, integrity and potential to mobilize radionuclides from, the aged debris pile.

Also, it turns out, that if the Cactus crater concrete containment structure on Runit Island were located in the United States proper (or subjected to U.S. regulatory authority), it would be formally classified as a Low-Level Radioactive Waste Disposal Site and be subject to stringent site management and monitoring practices (Davisson et al., 2012). In this instance, a long-term groundwater monitoring program would almost certainly form an integral part of these activities.

At the same time, it is recognized that groundwater contamination from beneath the containment structure reaching outflow points in the lagoon or on the ocean reef will be very rapidly diluted. Under this scenario, there will likely be little or no measureable or discernible increase in the radiation burden delivered to marine biota or the human population. As such, historical studies have generally been dismissive of any possible hazards associated with the containment structure by use of a simple inventory argument and the rapid turnover time of sea water inside the lagoon. Such arguments have failed to alleviate the concerns of the people of Enewetak and its leadership.

The 1986 Compact of Free Association (COFA) (P.L., 99–239 Stat 1770) between the United States and the Republic of the Marshall Islands provides for a “full settlement of all claims, past, present and future” related to the U.S. nuclear test program in the Marshall Islands. The need for site-specific radiological monitoring effort around the Cactus crater containment structure was recognized in the original provisions of the 5-year MOU agreement and, thereafter, brought to the attention of the DOI by the U.S. DOE and LLNL scientists. Sea-level rise and increases in the frequency and severity of major storm events (including typhoons) may also lead to changes in the forcing for groundwater flow beneath the dome, impact on the integrity of the containment structure and stabilized debris pile, and enhance leaching and migration of radionuclides away from the site. Livermore scientists have therefore supported the call by Marshallese authorities, including the EULGOV and its legal counsel, to develop a long-term, groundwater monitoring program on Runit Island. A Bill pertaining to continued monitoring of Runit Island was prepared and signed into law by President Obama during May 2012. The P.L. instructs the DOI to provide grant funding to the U.S. DOE to periodically conduct visual surveys of the containment structure, and analyze groundwater samples collected from inside and around the structure. The overall objective of the program is to make ‘a determination on whether the surveys and analysis of groundwater indicate any significant change in the health risks to the people of Enewetak from contaminants within the Cactus crater containment structure’.

P.L. 112–149 was developed to provide U.S. legislative authority outside of COFA and the U.S. Department of Energy’s Marshall Islands Program to address radiological concerns about leakage of radioactive waste from the containment structure into the environment. The goals of the groundwater monitoring program will be best met by developing a conceptual model of groundwater flow and mass-transport of radionuclides from the containment structure. The initial phase of the project will therefore focus on developing baseline measurement data on the time-evolution of water quality in the near-field environment around the containment structure under different release scenarios. High-resolution, contemporary measurement data will also be used to study the impact of forcing events such as tidal surges and storms on groundwater flow and mass-transport of radionuclides. These data and information are keys to providing understanding and interpretation of any long-term trends in groundwater quality inside and around *the* containment structure. In this way, the groundwater monitoring program will support the development of a full and comprehensive assessment of the potential health and ecological impacts of any leakage of radioactive waste from the containment structure, without relying on simple inventory arguments based upon the remobilization of radionuclides contained in lagoon sediments. In a very simplistic way, the groundwater monitoring program implemented under P.L. 112–149 could be viewed and presented publically as an 'early warning' system to assess changes in water quality before any radioactive material necessarily leaves the site boundary. As such, the groundwater monitoring program in the near-field environment of Runit Dome will support U.S. agency efforts to address the concerns of the Enewetak community in a more direct and definitive manner, and help build public confidence in the maintenance of a safe and sustainable resettlement program on Enewetak Atoll.

This report and the accompanying web accessible photo portfolio are intended to satisfy the requirements for year 2013 reporting of results of a visual survey of the concrete exterior of the containment structure conducted under clause (B)(ii)(I) of the P.L. The survey was designed to provide information on the overall integrity of the containment structure, as obtained from both visual photos and Non-Destructive Testing (NDT) techniques. The NDT techniques included Ground Penetrating Radar (GPR) for sub-grade evaluation, Impact Echo (IE) for concrete thickness and condition, and Spectral Analysis of Surface Waves (SASW) for overall concrete condition. These additional tests were performed as a preliminary step towards defining possible operational constraints and concerns about positioning a borehole drilling rig on the containment structure under the next phase of the project. It is only after drilling a network of strategically placed groundwater monitoring wells, placed inside and around the dome, that a scientifically credible monitoring program can be developed to fully realize the intent of clause (B)(ii)(II) of the P.L. This includes the need to develop high-resolution, baseline data and information on groundwater flow and water quality inside the crater debris, beneath the crater proper and in the surrounding subsurface portions of the island. Such baseline data are needed to properly assess the impacts of forcing events such as diurnal tides, storms and periods of high rainfall on the mass-transport of radionuclides. Moreover, the data and information developed from this baseline study will allow the U.S. DOE to make an informed decision on how frequently groundwater samples should be collected under a long-term monitoring program.

METHODOLOGY

The current visual photographic survey took place between 29 May and 5 June of 2013 in partial fulfillment of clause (B)(i)(I) of the P.L. to perform a visual study of the concrete exterior of the Cactus crater concrete containment structure on Runit Island. A Global Positioning System (GPS) was deployed on a second visit to the site in August 2013 to ascertain more precise survey data on the layout of the concrete panels, and to develop detailed contour maps showing voided or poorly supported and other reflective features in the sub-surface zone of the containment structure.

Upon arrival at Runit Island, the field team took immediate steps to remove dirt and sandy debris, pieces of chipped out concrete, rooting vines and other vegetative growth covering the containment structure (hereto known as *Runit Dome*). The vegetation appears to represent about 5 years of regrowth. It is not clear, however, how much of dirt and debris was left in place after the NSTec led visual survey and cleanup of the dome (NSTEC, 2008). In this instance, the top of the keywall and some bottom sections of ring row A on the southern fringe of *Runit Dome* were obscured by as much as 40 to 60 centimeters of coralline soil and beach sand. All this material was manually removed from the dome using hand tools. Several small trees growing over the dome were cut down with a chain saw and the stumps removed. Any remaining shrubs and rooting vines growing near the edge of the keywall were treated with *Spike* herbicide. Field workers were supplied with and instructed to wear appropriate Personnel Protective Equipment (PPE) depending on the nature of the task performed.

The photographic survey was performed using a Nikon D5100 digital camera. Typically, a single digital photo was taken and a written description of any defects prepared for each panel. A significant defect was loosely defined by a pocket of chipped or "spalled" concrete, or where a crack had formed in the concrete in excess of 2 to 3 millimeters in width, extending in any one direction by more than 40 to 50 centimeters. Additional photos were sometimes taken to highlight spall elements and/or cracks and voided areas in the concrete. Rooting vegetation was removed from along the seams and corners of panels prior to taking any archival photographs.

The coordinates of each panel corner were surveyed using a fully integrated Topcon - HiPer Real Time Kinematic (RTK)-Global Navigation Satellite System (GNSS) running on TopSURV field controller software. These coordinates are represented in this report as distances (x,y,z) in meters from the apex of the dome, where x is east, y is north, and z is the upwards elevation. In other words, (0,0,0) is the apex of the dome, and the northern most point of the dome might then be located by (+0,+57,-7.4). There were no preexisting geographical controls or benchmark sites available within a practical radius of the *Runit Dome*. As such, a RTK-GNSS benchmark site was created by drilling out a number of small holes, with an obvious center point, atop of an existing concrete block located about 100 meters from the edge of the dome (Fig. 7). The precise coordinates of the base station datum (N 11° 33' 8.75464"; E 162° 20' 45.09224") were then obtained from the local benchmark station data using OPUS (Online Positioning User Service) with normalization to the National Spatial Reference System (NSRS).

The RTK-GNSS system was also used to survey sixteen dome elevation points identified as 60 centimeter diameter painted red circles with an etched 'X' mark in the middle (Fig. 8). Pat Haggerty and Roger Kanealii first established the elevation points in 1983 using a self-leveling instrument (H&N, 1983b). Unfortunately, these data were not saved with the electronic archive copy of the 1983 survey report so it was not possible to evaluate changes in position of these points due to slab movement. The high quality survey data presented here will serve this purpose as part of any future visual surveys of the containment structure.

In addition, a number of panel corner locations (N=42) were re-occupied for a second time to assess the degree of reproducibility in the RTK-GNSS data. The mean difference and standard deviation between autonomous RTK-GNSS readings were 1.4$\pm$1.4 millimeters (max = 6.2 millimeters) in the easting direction (x coordinate), 1.7$\pm$1.3 millimeters (max = 6 millimeters) in the northing direction (y coordinate), and 1.1$\pm$0.7 millimeters (max = 2.8 millimeters) in elevation (z coordinate). Corner measurements were taken by extending a wooden paddle, with the RTK-GNSS prism pole seated inside

Fig. 7. RTK-GNSS benchmark site placed on a pre-existing concrete block located about 100 meters from *Runit Dome* (N 11° 33' 8.75464"; E 162° 20' 45.09224") [the survey position is represented by the center most hole drilled in the concrete].

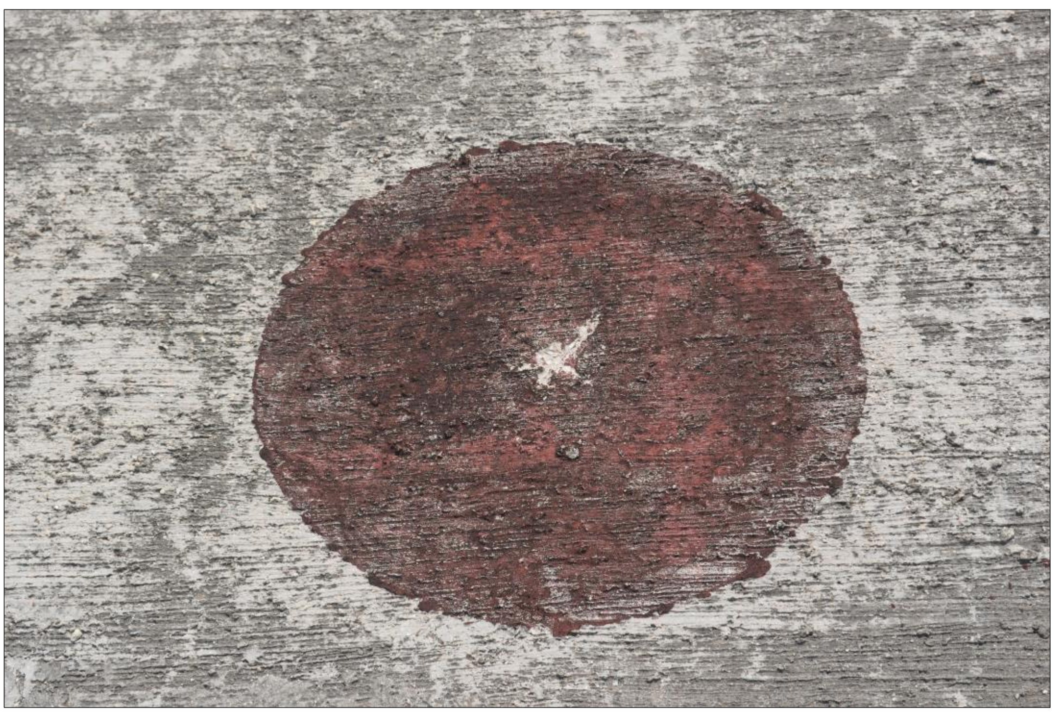

Fig 8. Photo of a dome elevation point developed during the 1983 visual survey of *Runit Dome* (and re-established during 2013).

a beveled hole, across opposite facing top and bottom corners of intersecting panels (see Fig. 9). As time permitted, a site survey was conducted to locate any pre-existing boreholes on or around the dome that could possibly serve as groundwater monitoring and sampling wells. Three cased drill holes established during 1980 NAS investigation were located - borehole CD-17 located on the dome near the center of panel C36, and borehole CD-15 and CD-16 located on land and hydrologically aligned downstream with borehole CD-17 on the western side of the containment structure (Ristvet, 1980). The concrete plug covering borehole CD-17 was successfully removed to expose a 5 centimeter diameter polyvinyl chloride (PVC) well pipe (Fig. 10). The PVC pipe supposedly extended down to a depth of 11.3 meters (Ristvet, 1980) but, in this instance, there appears to be some type of obstruction inside the pipe. Fortunately, we were able to place a submersible pump (MP-1 Grundfos Rediflo-2) down to a depth of approximately 5.2 meters or just below water level. The well was subsequently conditioned by pumping out several dead volumes of water above the pump head, and about 13 liters of unfiltered water collected for radiometric analysis in a collapsible, plastic container. The water contained an obvious hydrogen sulfide odor. Efforts to flush out the existing monitoring wells on land (borehole CD-15 & CD-16; Ristvet, 1980) using a large capacity Honda sludge pump and circulating seawater were only partially successful. We have yet to determine if it will be possible to use these historical boreholes as part on the groundwater monitoring program. An initial groundwater sample was obtained from borehole CD-16 during the August 2013 mission along with a second groundwater sample from borehole CD-17. Results of analyses of these samples will be published elsewhere.

Fig. 9. Photo showing the method for positioning the prism pole while surveying panel corners (RTK-GNSS Survey, November 2013) [the end of the pole is seated inside a wooden paddle containing a beveled out hole].

Fig. 10. Recovered borehole (CD-17), originally established in support of a NAS investigation conducted during March 1980 (Visual Survey, May 2013).

A portable weather station manufactured by Campbell Scientific (CSI) was also erected during the course of the visual survey. This automatic station, which includes a Vaisala WS425 19 sonic anemometer and two tipping-bucket rain gauges, will provide continuous collection of hourly averaged measurements of wind speed and direction, and rainfall, over the lifespan of the project (Fig. 11).

RESULTS AND DISCUSSION

The results of the cleanup actions to remove soil and debris, rooting vines and other vegetative growth covering the lower sections of the dome can clearly be seen in the comparative photos shown below (Fig. 12-13). Future visits to the site should evaluate the rate of encroachment of rooting vines over the dome, and determine the need to introduce a more rigorous vegetation eradication program. This action may be necessary to eliminate the role that rooting vegetation may play in causing the concrete to crack and spall along the seams and in panel corners (Fig. 14-15).

A description of observed defective elements and accompanying photo(s) for each panel are shown in Appendix A. The graphic illustration overlapping each panel photo depicts the relative positioning of the panel within the circular shaped outline of the dome shaped containment structure. High-resolution electronic copies of the main archival photo of each panel can be viewed and downloaded online using the enlargement feature provided. This was done to allow full access to photos in assessing future change in deterioration of the concrete. It is expected that under the P.L., the visual survey of *Runit Dome* will be 'conducted not less frequently than every 4 years'. The RTK-GNSS survey data for each panel corner are given in Appendix B. The arithmetic mean, maximum and minimum elevation (in meters) of the bottom, left-hand corner of panels occupying each ring row are shown in Table 1.

Fig. 11. A portable weather station erected in close proximity to Runit Dome (Visual Survey, May 2013).

Table 1. Arithmetic average vertical elevation of the bottom, left-hand corner of panels contained in each ring row covering Runit Dome.

Ring Row	Measured Elevation, meters		
	Average	**Max.**	**Min.**
A	-7.364± 0.073	-7.216	-7.505
B	-5.920± 0.125	-5.603	-6.097
C	-4.534± 0.040	-4.411	-4.616
D	-3.382± 0.050	-3.283	-3.511
E	-2.454± 0.036	-2.394	-2.548
F	-1.679± 0.026	-1.632	-1.737
G	-1.100± 0.024	-1.048	-1.167
H	-0.612± 0.022	-0.571	-0.646
I	-0.359± 0.022	-0.307	-0.410
J	-0.193± 0.014	-0.157	-0.223
K	-0.080± 0.008	-0.054	-0.093
L	-0.039± 0.013	-0.024	-0.062
Apex	0.000	0.000	0.000

The majority of concrete panels contained at least some minor defects consisting mostly of chipped “spalled” panel corners, surface cracks running across the panel segments and/or rooting vines and grass growing along panel seams or in panel corners. The majority of cracks appearing across the face of the panel segments were mostly less than 1 to 2 millimeters in width. Many of the cracks contained chipped “spalled’ edges with the degree of spalling varying between the panels. In general, the cracks and spalls observed in the concrete were not considered structural in nature because there was no evidence pointing towards significant loss of ability of the concrete to bind constituents together. The number of panels containing significant spall elements was highest among panels in the lower ring rows (A through C). The intermediate ring rows (D through F) contained both the highest density and the most significantly cracked panels.

In general, cracks in the concrete are likely to have been caused by long-term drying shrinkage of the concrete, and the chipping of edges and spalling by thermal movement of the slab due to expansion and contraction (Concrete Science, Inc.). Based on a review of historical photos, the degree of cracking and spalling of concrete panels covering the dome does not appear to have changed significantly since 2008 (NSTec, 2008) but, it is clear, the number of panels showing some level of deterioration has slowly increased since the time of construction of the dome (refer H&N, 1983a; 1983b; 1984; 1989).

There also appears to be some degree of weathering of the surface of concrete panels as identified in this report by contrasting variations in roughness and discoloration of the original broom finished concrete (Fig. 16). Also, cracks appearing across the top of the concrete panels can easily be identified in photographs by streaks of discoloration (darkened appearance) extending along the crack lines (Fig. 17). Variations in color between and across different concrete panels can also observed in historical photos of the dome (see NSTec, 2008).

The presence of iron oxide in cement typically gives concrete a grey color. In addition to the construction method, the color of finished concrete can be affected by many factors including the iron oxide content of the cement, the water to cement ratio used in making up the original slurry, and on the type and amount of aggregate and curing compound used (Concrete Science, Inc., 2013). Color and durability can also be affected by the presence of and variations in the salt content of the concrete, especially with respect to presence of chloride and sulfate.

As previously stated, the concrete cap covering *Runit Dome* was constructed from imported cement, mixed local aggregate and seawater. It is therefore feasible that some panels were made up of a slurry mixture containing more seawater than others. As a result, variations in color and the weathered appearance of some concrete panels may be caused by preferential aging of concrete containing a higher average concentration of salt from the added seawater.

Similarly, streaks of discoloration along crack lines and seam edges may be caused by the action of rainwater penetrating down into the cracks and leaching out sea salts from below the surface of concrete. The salt then re-deposits by drying on the surface of the concrete to give each crack line a distinctive appearance. In order to determine the exact cause for the weathered appearance and discoloration of the concrete panels, petrographic and chemical analyses need to be performed on concrete cores collected from a series of light and dark colored patches of concrete from different panels around the dome (Concrete Science, Inc., 2013).

Fig 12. Vegetation growth over the face of *Runit Dome* (Initial conditions, Visual Survey, May 2013).

Fig 13. View of *Runit Dome* after removal of vegetation, dirt and debris (Final conditions, Visual Survey 2013).

Fig 14. A photo of a tree stump located over the keywall (the stump was later removed) (Visual Survey, May 2013).

Fig 15. Plastic bags of concrete rubble and other loose debris collected from around *Runit Dome* (Visual Survey, May 2013) [The volume of debris collected could potentially be used to assess the extent of spalling of concrete between surveys].

Fig 16. A concrete panel (center) showing signs of weathering and discoloration.

Fig. 17. Concrete panels showing streaks of discoloration running along crack lines.

There were at least nineteen (19) concrete panels meeting the definition of containing significant spall or crack elements (Fig. 18-36). Cracks in the corner of panel C-22 and C-43 extend down through the entire concrete cap where it was possible to lift out the concrete segment to reveal the surface of the concrete-contaminated soil-grout mixture below. The presence of these two more severely-cracked panels was also called out in the 2008 Runit Survey report prepared by NSTec (NSTec, 2008) but no action was taken to initiate any repairs. Other photos (Fig. 37-40) highlight more typical observation of cracks in the concrete running either horizontally or vertically across the face of the panels. As previously indicated, many of these cracks contain chipped "spalled' edges.

In general, the Cactus crater containment structure appears to be structurally sound. However, it is the opinion of this author that any obvious, visually-defective concrete panels covering the dome represent a potentially serious public perception-management problem. This would especially be true of making definitive statements or drawing publically acceptable conclusions about the overall integrity and radiological safety of *Runit Dome*. For example, the existence of the vegetation growing in the cracks or between panel segments may be considered illustrative of the potential for meaningful infiltration of rainwater down through the top of dome, and also convey a general sense of dilapidation of its function. Moreover, rainwater penetrating down through cracks or between the seams of concrete panels could also affect the potential to dissolve and transport radionuclides down through the debris pile, and into the underlying groundwater. If this is true, then some consideration may need to be given to repairing the cracks, and possibly sealing up the seams between individually formed panels, before developing a long-term groundwater monitoring program to assess changes in water quality beneath and surrounding the containment structure. This work should be performed under the supervision and with on-site training from a licensed Materials and Structural Engineer.

Fig. 18. Spalling of concrete along the bottom seam adjoining the keywall on panel A2.

Fig. 19. Spalling of concrete along the bottom seam adjoining the keywall on panel A4.

Fig. 20. Cracked concrete with spalled edges on the upper, left-hand corner of panel A5.

Fig. 21. Cracked concrete with minor spalling along the seam adjoining the keywall on panel A8.

Fig. 22. Spalling of concrete along the seam adjoining the keywall on panel A9.

Fig. 23. Spalling of concrete along the seam adjoining the keywall on panel A19.

Fig. 24. Spalling of concrete along the seam adjoining the keywall on panel A24.

Fig. 25. Spalling of concrete in the bottom right-hand corner along the seam adjoining the keywall on panel A28.

Fig. 26. Spalling and cracked concrete in the bottom right-hand corner and along the seam adjoining the keywall of panel A31.

Fig. 27. Spalling of concrete along the seam adjacent to the keywall in the bottom right-hand corner of panel A37.

Fig. 28. Cracked concrete with spalled edges on the lower, right-hand corner of panel A38.

Fig. 29. Spalling and cracked concrete along the seam adjacent to the keywall in the left-hand corner of panel A48.

Fig. 30. Spalling of concrete along the seam adjacent to the keywall on panel A55.

Fig. 31. Spalling of concrete along the seam adjacent to the keywall on panel A56.

Fig. 32. Major spalling of concrete on the lower, right-hand corner of panel B1.

Fig. 33. Cracked concrete with spalled edges on the lower, left-hand corner of panel B40.

Fig. 34. Cracked concrete with spalled edges on the lower, right-hand corner of panel B53.

Fig. 35. Cracked concrete with spalled edges on the bottom, right-hand corner of panel C22_duplicate (position C24) [Refer Appendix I for extra panel positioning].

Fig. 36. Major spalling of concrete on the lower, right-hand corner of panel C43.

Fig. 37. A visually-defective concrete panel (F2) showing numerous minor surface cracks.

Fig. 38. Visually-defective concrete panels (D21, E15, E22, G29) showing minor to moderate size cracks with chipped “spalled’’ edges.

Fig. 39. A visually defective concrete panel (E12) showing a minor to moderate size crack extending upwards across the entire face of the panel segment.

Fig. 40. A more severely cracked concrete panel (D15) with chipped "spalled" edges along the cracks.

Vertical Elevation Data

RTK-GNSS data for sixteen elevation points are shown in Table 1. These data were collected with the end of the prism pole resting directly in the center of the etched 'X' mark (Fig. 9). The vertical elevation points are arranged symmetrically around the face of the dome as shown in Fig. 41.

Table 2. Vertical elevation data for a series of reference points established over the face of the concrete façade covering *Runit Dome*.

Panel ID	Easting (x, meters)	Northing (y, meters)	Elevation (z, meters)
A37	6.074	-56.387	-7.091
D26	4.018	-37.729	-3.309
E25	-17.920	-22.283	-1.885
G20	2.046	-18.940	-0.839
E15	23.194	-16.694	-1.964
A53	-56.218	-6.008	-7.200
D36	-37.675	-4.075	-3.352
G26	-18.911	-2.046	-0.848
G8	18.941	1.985	-0.857
D14	37.703	3.992	-3.349
A22	56.340	5.951	-7.366
E34	-22.258	17.895	-1.916
G2	-2.035	18.864	-0.853
E7	17.907	22.168	-1.898
D4	-4.056	37.648	-3.353
A7	-6.035	56.251	-7.251

Project Continuation and Concrete Repair Recommendations and Strategies

The visually-defective concrete panels covering *Runit Dome* will undoubtedly lead to questions concerning the overall structural integrity and radiological safety of the Cactus crater containment structure. These visually-defective panels should be further inspected and repaired with oversight from a licensed Materials and Structural Engineer. Such actions will potentially enhance the level of public trust in the U.S. DOE, and help alleviate negative, public perception and sentiment over *Runit Dome*. Also, the integrity of the underlying debris pile in supporting the dome elements, in full or partially, is a germane consideration here because the visually-deflective concrete panels covering Runit Dome will be viewed by the public as a determining factor in assessing the overall effectiveness of the containment structure in preventing harmful quantities of radioactivity from becoming available for human exposure.

The repair of any cracks in the concrete also serves the dual purpose of helping minimize rainwater infiltration down through the debris pile, which may possibly impact on radionuclide mobility and groundwater hydrology. Details describing the results of the sub-grade NDT techniques and

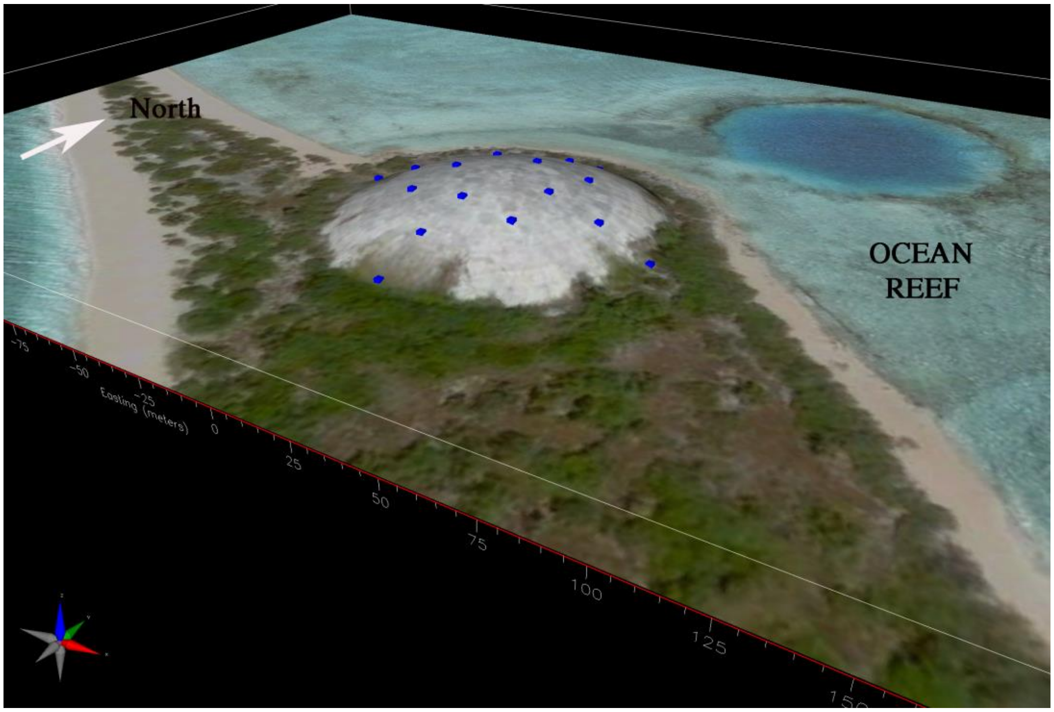

Fig. 41. A Google image showing the position of dome elevation points extending across the top of *Runit Dome***.**

an outline of proposed actions to be conducted under Phase II of this project will be presented elsewhere.

The activity concentrations of iodine-129 (^{129}I), ^{137}Cs and Pu isotopes were measured in a single, unfiltered, surface groundwater sample collected during May 2013 from the 1980 NAS borehole location (CD-17) (Fig. 10). For each radionuclide, the level of contamination in the groundwater sample was about one thousand times higher than what is typically observed in the open ocean (Hamilton et. al., in prep.). The significance of these findings is not clear at this time because we have no comparative measurement data for groundwater from deeper inside the borehole, from other boreholes locations inside or around the dome nor from other parts of Runit Island. Also, we are not fully cognizant of all possible geochemical process that may be influencing the solubility or retention of radionuclides contained in the aged debris pile. Supplementary analyses do show that this surface groundwater sample has a low salinity (~2.6 parts per thousand) and an unusually high pH of around 12.4. In combination with the radionuclide concentration data, this may indicate that aged freshwater is pooling under *Runit Dome* and forming a potential point-source of radioactive contamination. At the same time, pressure gauge readings indicate that the water level inside the dome borehole is being strongly influenced by tidal fluctuations (Hamilton et al., in prep.). This is a clear indication that there is some form of communication between the groundwater inside the dome and the surrounding ocean or lagoon, as previously postulated by the NAS (NAS, 1980). Additionally, the radionuclide content of the debris pile material and of the underlying groundwater may have been affected or influenced by tidal cyclic flushing effects for some time and, along with geochemical considerations, may complicate interpretations of their current magnitudes.

It is plausible that higher than average concentrations of fallout radionuclides have been flushed out of the debris pile into the nearby groundwater via cyclic advective and dispersive mass transport processes for some time. Furthermore, major forcing events such as storm surges or periods of very high rainfall may have additional dramatic, short-term effects on water quality and radionuclide migration. In this example, long-term changes in water quality and groundwater flow may be totally biased by spatial and temporal variability caused by seasonality or multiple short-term forcing events such as tides and episodic storm surges (Davisson et al., 2012). Consequently, it will be necessary to drill a wider network of groundwater monitoring and sampling wells at the site, and to develop high-resolution, baseline data on water levels and water quality. We envisage the need to drill 3 or more groundwater sampling wells, located both inside and around the dome, as well as at least one additional groundwater well at a control site elsewhere on the interior of Runit Island. The baseline groundwater monitoring, sampling and analysis program should be performed over a timescale of not less than 18 months with routine, monthly sampling of groundwater from each well. Additional groundwater samples should be collected immediately following any notable forcing events. Analyses should be performed for soluble, particulate and colloidal radionuclides as well as for other relevant water-quality parameters and/or stable analogs, e.g., salinity, pH, redox potential, stable cesium and strontium. Such efforts will also provide essential data and information needed to perform trending and uncertainty analysis, and establish a scientific basic for determining how frequently groundwater samples should be collected under a long-term, monitoring program.

It is also anticipated that there will be a need to fully characterize the substrate material recovered from any drilling operations. This will be done to measure the present-day inventory and isotopic mix of radionuclides, and assess the geophysio-chemical conditions and quality of cementation of materials, within the aged debris pile, and to establish possible boundary conditions for modeling of solid phase-aqueous interactions affecting radionuclide solubility and mass-transport.

Overview of Sub-Grade Testing Results

Olson Engineering, Inc. conducted a NDT investigation in conjunction with the 2013 visual survey of *Runit Dome* (Olsen Engineering, Inc. 2013). The testing was performed to evaluate the presence of sub-grade support of the concrete as well as to determine the thickness and overall condition of the concrete cap. A more detailed analysis of the sub-grade tests will be presented elsewhere (Hamilton et al., in prep).

In summary, a preliminary analysis of the 400 MHz GPR data indicates that only two areas – representing about 0.06 % of the total area scanned – are suspected to be poorly supported or “voided”. These two suspected voids exist at panels A42 and A45. Only 0.85% of the measurements were considered “questionable”, with the possibility of containing a minor void or loose material under the concrete cap. However, the “questionable” zones from the 200 MHz antenna match poorly to the “questionable” zones from the 400 MHz antenna, indicating that these reflections may be due to small changes in the supporting material and are less likely to be a true indication of a minor void or poor support.

The design thickness of the concrete cap was 45 centimeters (DNA, 1981). The IE and SASW tests indicate that the majority of the concrete is in a structurally “sound” condition but the thickness of the cap is highly variable. The average thickness of the concrete cap was measured at 43 centimeters

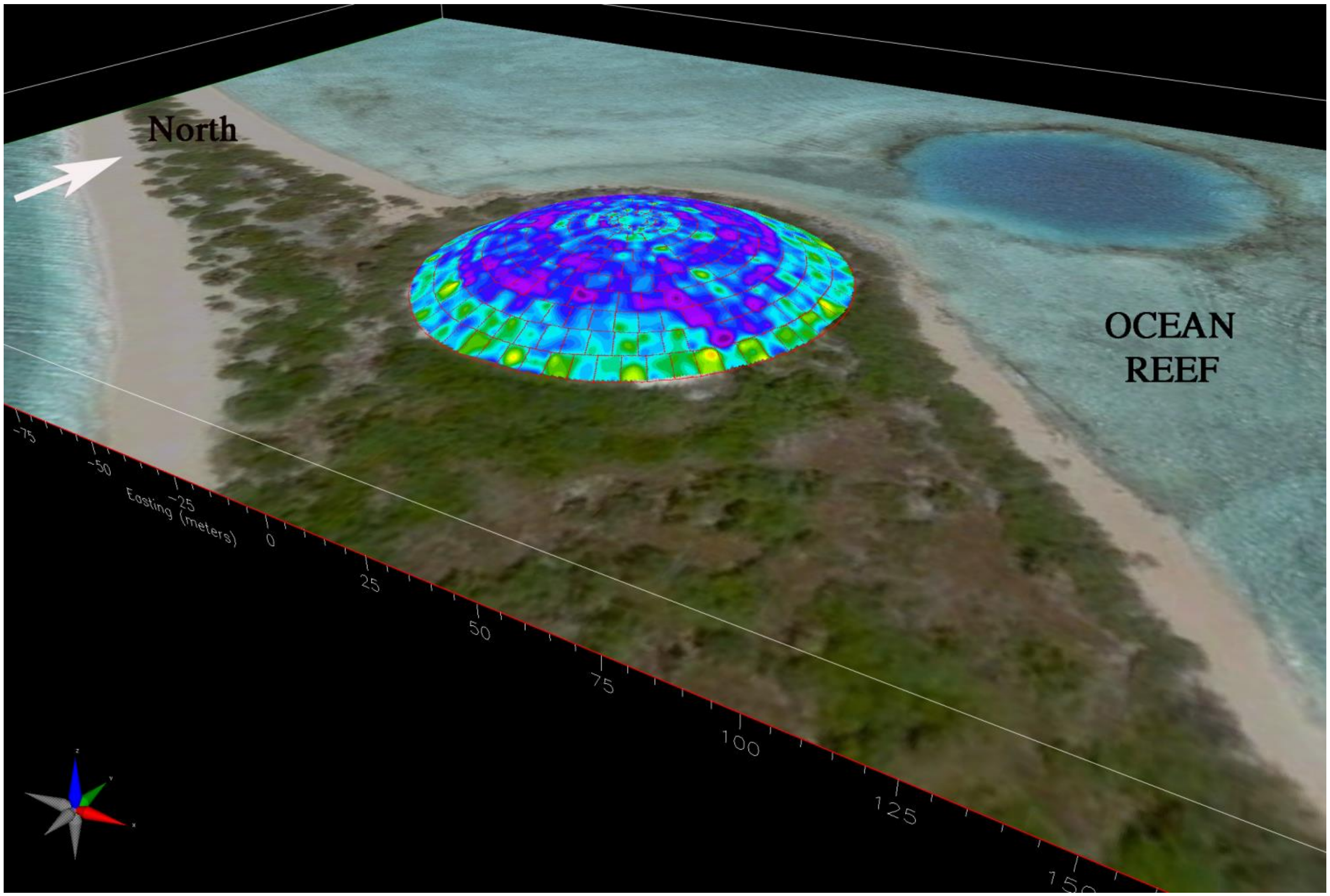

Fig. 42. A Google map image showing a contour-plot overlay of the relative thickness of the concrete cap covering *Runit Dome* (*Impact Echo (IE) measurements with the thinnest areas around the middle of the dome represented in a darker bluish, purple shade*) [compiled from data collected by Olsen Engineering, Inc., Visual Survey, May 2013].

with a standard deviation of 7.2 centimeters (Coefficient of Variation = 16.6 percent). The range in thickness of the concrete varied between 24 and 71 centimeters. A contour plot of the relative thickness of the concrete cap based on IE data is shown in Fig. 42. In general, panel ring rows in the middle of the dome (specifically ring row D, E, and F) have a majority of readings less than the design thickness. Panels around the base (ring row A and B) and on the apex of the dome (ring row I, J, K, and L) tend to exceed the design criterion.

We conclude from these supporting studies that the concrete cap covering *Runit Dome* is structurally sound and is shown to be sitting in intimate contact with the mounded debris pile below. The integrity of the concrete cap and underlying debris pile in supporting the dome elements provides a level of confidence that there is no immediate danger of the dome collapsing. Moreover, the NDT data combined with proposed tensile strength testing of concrete cores collected from the concrete façade should provide sufficient data to make an informed decision about the load-bearing capacity of the structure to support future drilling operations.

Reference Photo of the Runit Dome Northern Shoreline

In order to gauge potential impacts of the major storm events and sea-level rise on the shoreline surrounding *Runit Do*me, a decision was made to include a reference photo in this, and in all subsequent, visual survey reports. A reference photo (Fig. 43) of the current island beach configuration was taken from the apex of *Runit Dome* looking towards the north-east end of the island.

SUMMARY

This work was performed under the auspices of the U.S. Department of Energy (DOE) by Lawrence Livermore National Laboratory (LLNL) in support of Public Law (P.L.) 112–149 as cited under the Insular Areas Act of 2011 and amended in Section 103(f)(1) of the Compact of Free Association Amendments Act of 2003 [48 U.S.C. 1921b(f)(1)]. The relevant section of the P.L. appears under the title to 'SEC 2 Continued Monitoring of Runit Island', clause (B)(i) Cactus Crater Containment and Ground Water Monitoring, part (I) a visual study of the concrete exterior of the Cactus crater radioactive waste containment structure on Runit Island.

This report was prepared to satisfy the reporting requirements specified under clause (B)(ii)(I)(aa) of the P.L.

The Cactus crater waste contaminant structure on Runit Island continues to exhibit levels of cracking and spalling of concrete within the protective façade covering the waste pile but is generally considered to be structural sound. These findings are supported by the results of supplemental, subgrade nondestructive tests performed by Olsen Engineering, Inc.

Key considerations and recommendations for developing a scientifically defensible and credible survey and groundwater monitoring program on Runit Island are as follows;

1. Develop and implement a program to eradicate the growth of rooting vines and scrub vegetation encroaching on *Runit Dome* in order to reduce the potential for vegetation to increase the rate of spalling of concrete along the seams and in corners between panel segments.

2. Develop and implement a program to repair visually-defective concrete panels in conjunction with a licensed Materials and Structural Engineer. These actions are considered necessary in order to;
   (i) Reduce the potential for rainwater infiltration down through the waste pile and into the underlying groundwater, and
   (ii) Help improve the level of public trust and address the negative perception that residents and visitors to Runit Island will likely gain from viewing of any major spalls or cracks in the concrete cap.
3. Develop and implement a program to collect representative concrete cap core samples from different locations around *Runit Dome* for petrographic and chemical analysis. The measurements should include compressive and split tensile strength testing, microscopic analysis, and measurement of acid soluble chloride and sulfate profiles.
4. Consider the need to drill a network of groundwater monitoring and sampling wells inside and around *Runit Dome*, and ultimately meet the intent of P.L. 112–149 in a scientifically meaningful and defensible manner. The initial phase of this groundwater monitoring program should include the following subtasks;
   a) Continuous monitoring of meteorological forcing conditions such as wind speed and direction, and rainfall.
   b) The collection and characterization of the solid phase debris samples from the drilling operation. It is expected that these data will advance understanding on;
      (i) The present-day, radionuclide inventory and isotopic mix of radionuclides contained in the debris pile;
      (ii) The geophysio-chemical properties of materials contained in the aged debris pile, and their radionuclide exchange capacity with groundwater;
      (iii) Boundary conditions for modeling of solid phase-aqueous interactions affecting radionuclide solubility and mass-transport; and
      (iv) The nature and quality of cementation of the materials contained in the aged debris pile.
   c) For a period of not less than 18 months, monitor water levels and collect a monthly time series of groundwater samples for analysis of radionuclides and other water quality parameters. Along with the collection of meteorological data under part a), these baseline data and information will be used to;
      (i) Aid interpretation of short-term changes or long-term trends in water levels as a means to establish the nature of transient hydraulic forcing effects in the area (as from tides);
      (ii) Aid interpretation of short-term changes and long-term effects in associated water quality conditions (radionuclide content, salinity, pH, redox conditions, etc.), as influenced by these forcing effects;
      (iii) Provide a scientific basis for establishing how frequently groundwater samples should be collected under a long-term groundwater monitoring program;

(iii) Provide a scientific basis for establishing how frequently groundwater samples should be collected under a long-term groundwater monitoring program;

(iv) Contribute to the development of a conceptual model of groundwater flow in the system; and

(v) Support the development of appropriate radionuclide mass-transport and risk-assessment models, with uncertainty analysis, for describing the potential, long-term health and ecological impacts of any leakage of radioactive waste from the site under different release scenarios.

5. As a means to enhance the conceptual model development process described above, provide age dating of selected groundwater samples to determine the residence time of the groundwater below and around the dome. This work should be conducted with a view towards assessing the extent of rainwater infiltration through cracks and seams in the concrete. It is expected that infiltration of rainwater down through the waste pile and into the groundwater may dramatically impact groundwater flow and water quality. It is therefore essential to first develop an understanding of the dynamics of these processes before embarking on a major groundwater monitoring program. In a worse-case scenario, it may be necessary to repair the cracks and seal the joints between panel segments to reduce the potential for mobilization of radionuclides contained in the waste pile and, as a result, limit the accumulation of contaminated freshwater pooling beneath the dome that could eventually migrate into the subsurface, marine environment.

Acknowledgement

The Cactus crater waste containment and ground-water monitoring program conducted under P.L. 112–149 is funded by the U.S. Department of Energy (DOE) with a supplemental grant from the Department of Interior (DOI) through the Technical Assistance Program of the Office of Insular Affairs. I thank Barry Kirkendall, Jeff Wagoner, and Mike Gerhard at LLNL for technical and scientific support. Logistics support for the field program was performed under a service subcontract awarded by the Lawrence Livermore National Laboratory (LLNL) to International Outreach Services (IOS), Inc. I thank Mr. Lance Yamaguchi and his team at IOS, the Captain and crew of the vessel *Windward*, and local field workers on Enewetak for operational support. Mr. Frank Gouveia was responsible for erecting the weather station, and conducting the GPS survey of the dome under a service contract with IOS, Inc. Ms. Martha DeMarre, Nuclear Testing Archive (NTA), National Security Technologies LLC, provided invaluable assistance in locating and supplying archival copies of historical survey reports and photographs. I also thank Ms. Nanette Sorensen at LLNL for administrative support. This report has benefited from critical reviews performed by Drs. Andrew Tompson and Lee Davisson at LLNL, Drs Patricia Worthington and Gerald Petersen, and Mr. William Jackson, at the U.S. DOE, and Dr. Byron Ristvet at DTRA.

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Fig 43. View from atop of *Runit Dome* showing the beach configuration on the north end of Runit Island at low tide (Reference Photo, May 2013).

Appendix A

Photos and a Description of Individual Concrete Panels Forming Part of the Cactus Crater Containment Structure on Runit Island (Visual Survey, 29 May–5 June, 2013)

CAP SECTION: Panel A1 (no ID)

Description:

The panel contains no identification markings but occupies position A1. No significant or obvious interior cracks extending across the top of the panel. The surface of the concrete appears to have been refinished. There are some minor cracks and spalling of concrete in the upper right-hand corner of the panel, and along the seam adjacent to the corner intersection between panel B1 and B2.

CAP SECTION LOCATION: Panel A2

Description

Some rooting vegetation removed from along the panel seams. There is significant spall of concrete (about 2-3 meters wide, and up to 5-10 centimeters deep) running along the bottom seam adjacent to the keywall.

CAP SECTION LOCATION: Panel A3

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Some rooting vegetation removed from along the seams. Some minor spalling/chipping of concrete in the upper left-hand corner of the panel.

CAP SECTION LOCATION: Panel A4

Description

The panel has a rough and weathered appearance. Some rooting vegetation removed from along the panel seams. There is significant spall (app. 3 to 5 centimeters deep) of concrete along the bottom seam of the panel adjoining the keywall.

CAP SECTION LOCATION: Panel A5

Description

Some rooting vegetation removed from along the panel seams. There is a significant cracked section of concrete (about 1.5 meters in length) appearing along the upper left seam. Also, a small void (hole) has formed about 30 centimeters from the base on the right-hand side of the panel.

CAP SECTION LOCATION: Panel A6

Description

The panel has a rough and weathered appearance. Some rooting vegetation removed from along the panel seams. Minor spalling of concrete observed along the seam adjacent to the keywall.

CAP SECTION LOCATION: Panel A7

Description

The panel has a relatively rough appearance. Some rooting vegetation removed from along the seams. Minor spalling of concrete observed along the seam adjoining the keywall. Panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel A8

Description

The panel has a relatively rough appearance. Some rooting vegetation removed from along the seams. Cracked/spalled concrete observed along the seam adjoining the keywall (about 1 meter x 40 centimeters in area).

CAP SECTION LOCATION: Panel A9

Description

The panel has a relatively rough appearance. Some rooting vegetation removed from along the seams. A surface crack observed extending across the middle of the panel segment. Significant spalling of concrete observed along the seam adjacent to the keywall (app. 5 centimeters deep, and 60 x 30 centimeter in area).

CAP SECTION LOCATION: Panel A10

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough appearance. Some rooting vegetation removed from along the seams.

CAP SECTION LOCATION: Panel A11

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a weathered appearance. Some minor spalling of concrete observed in the upper right-hand corner of the panel. A scrub tree found growing over the keywall and base of the panel was cut down, and the stump removed.

CAP SECTION LOCATION: Panel A12

Description

No significant or obvious interior cracks extending across the top of the panel. The panel appears rough and weathered. Some rooting vegetation removed from along the seams.

CAP SECTION LOCATION: Panel A13

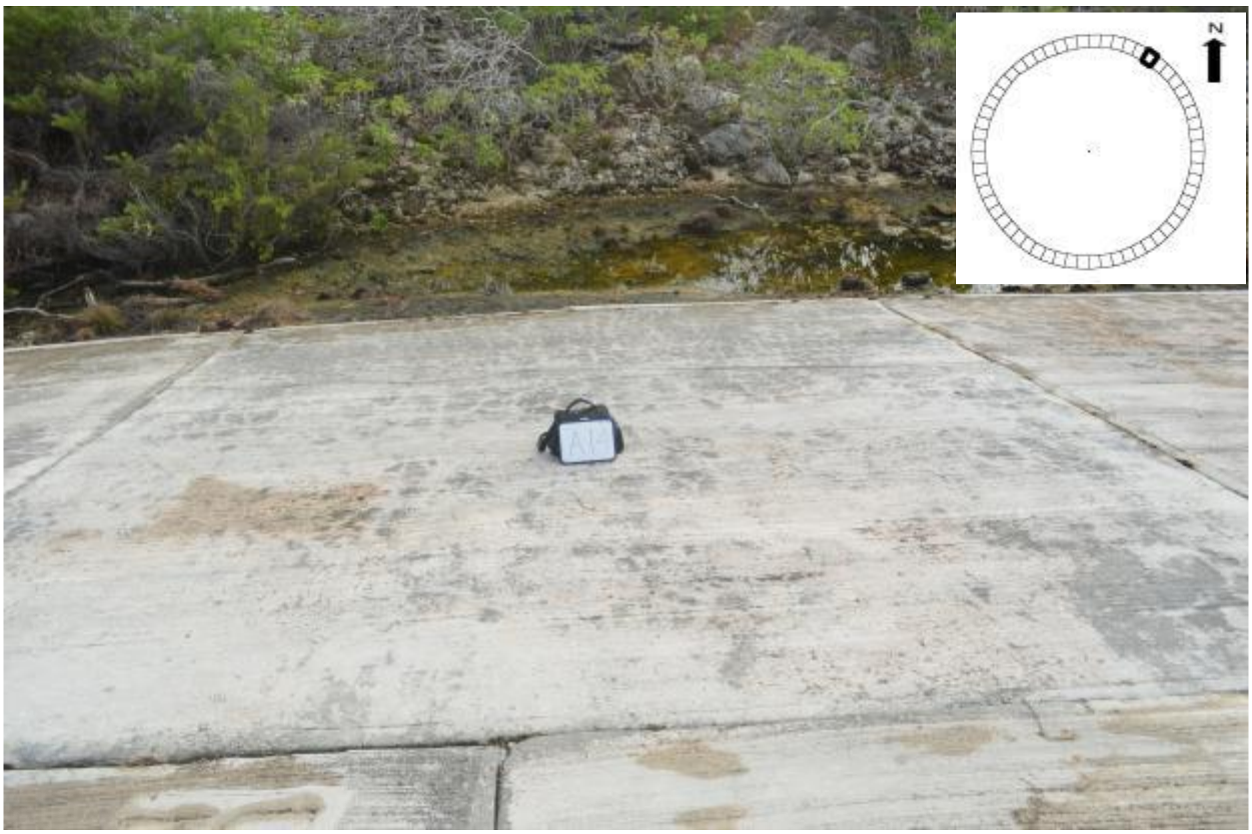
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough weathered appearance. Some rooting vegetation removed from along the seams. Some minor spalling of concrete observed in the upper left-hand corner of the panel.

CAP SECTION LOCATION: Panel A14

Description

The panel has a relatively rough weathered appearance. Some rooting vegetation removed from along the seams. A surface crack observed traversing across the panel from a mid-point on the left and intersecting with the right-hand seam about 3 meters up from the bottom of the panel.



CAP SECTION LOCATION: Panel A15

Description

The panel has a rough appearance. Some rooting vegetation removed from along the seams. A minor surface crack observed traversing about 1 meter down from the top seam about 1.3 meters from the right-hand corner of the panel.

CAP SECTION LOCATION: Panel A16

Description

Some rooting vegetation removed from along the seams. A visible crack observed traversing across the segment at a mid-point up the panel.

CAP SECTION LOCATION: Panel A17

Description

No significant or obvious interior cracks extending across the top of the panel. The upper and lower sections of the panel have a relatively rough appearance Some spalling of concrete along the keywall and adjoining bottom edge of the panel. Some cracked with chipped out edges observed along the left seam overhanging panel A18.

CAP SECTION LOCATION: Panel A18

Description

No significant or obvious interior cracks extending across the top of the panel. The lower portion of the panel has a rough appearance. Some rooting vegetation removed from along the seams. There is minor spalling of concrete in the upper right-hand corner of the panel, and along the base adjoining the keywall.

CAP SECTION LOCATION: Panel A19

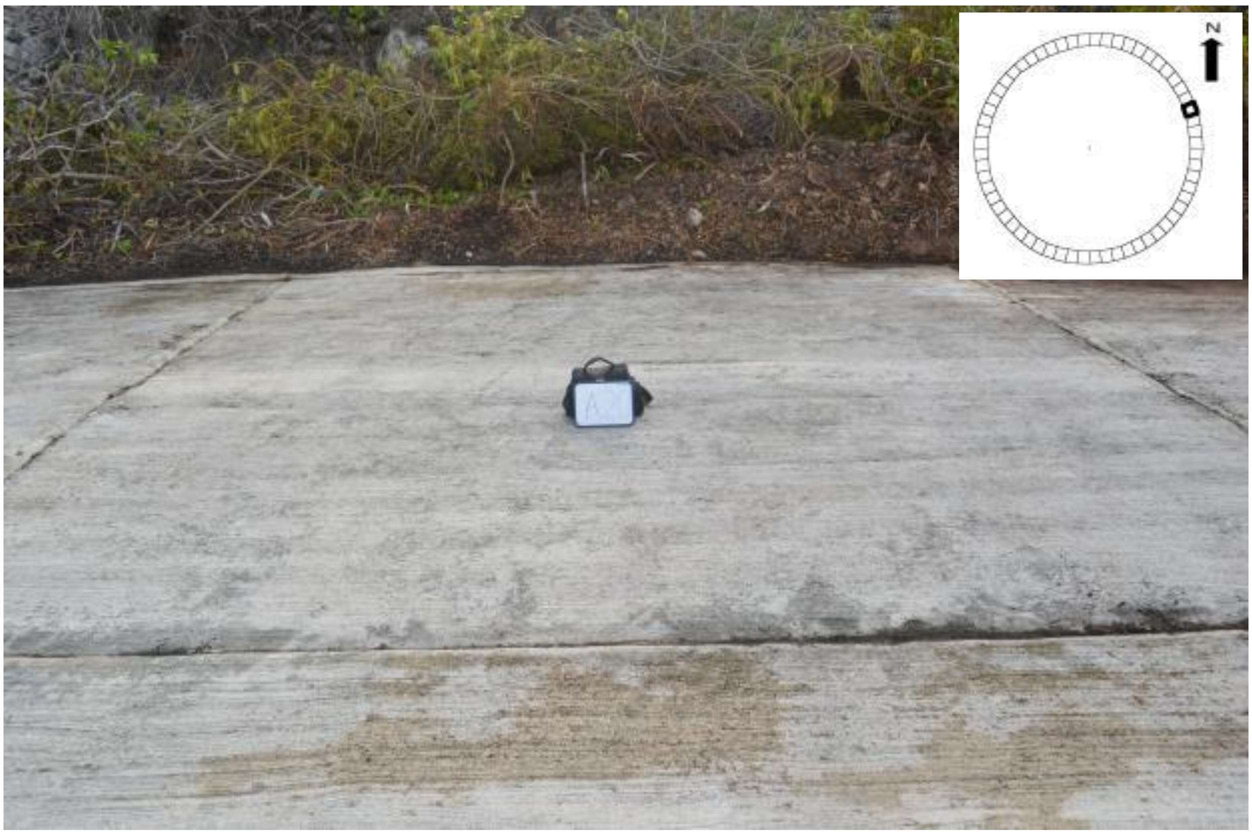
Description

The panel has a rough and weathered appearance. There is major spall of concrete along the base of the panel adjoining the keywall (app. 1.2 meters x 30-40 centimeters in area). There is also a visible crack in the concrete extending up through the middle of the panel, and minor spalls appearing along the left-hand seam.

CAP SECTION LOCATION: Panel A20

Description

Obvious spall of concrete along the bottom seam adjacent to the keywall (app. 1 to 2 centimeters deep, and 30 to 60 cm in area). Rooting vegetation removed from along the seams.



CAP SECTION LOCATION: Panel A21

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough appearance. Minor spalling of concrete observed along the bottom seam adjoining the keywall, and in the upper left-hand corner of the panel. Rooting vegetation removed from along the seams. A scrub tree overgrowing the keywall was cut down, and the stump removed.

CAP SECTION LOCATION: Panel A22

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the seams. Minor spalling of concrete observed in the upper right-hand corner of the panel, and in the joint intersecting with panel B21. This panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel A23

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the seams.

CAP SECTION LOCATION: Panel A24

Description

The panel has a rough and weathered appearance. A significant spall of concrete is visible along the seam adjacent to the keywall (several centimeters deep, and about 80 x 30 centimeters in area).

CAP SECTION LOCATION: Panel A25

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough appearance. Minor spalling of concrete observed on the upper left seam of the panel, and along the seam in contact with the keywall.

CAP SECTION LOCATION: Panel A26

Description

The panel has a rough and weathered appearance. Some spalling of concrete observed along the bottom seam in contact with the keywall and along the top seam, and in the top left-hand corner, of the panel. A scrub tree overhanging the keywall was cut down and the stump removed. A crack was observed on left side of the panel, extending out for a distance of about 4 meters across the panel.

CAP SECTION LOCATION: Panel A27

Description

There are only faint remnants of etched out panel ID marking still visible. There is a significant spall (several centimeters deep, and app. 70 x 40 centimeters in area) in the concrete in the lower left-hand corner, and several other minor spalls appearing both along the bottom and top seams of the panel.

CAP SECTION LOCATION: Panel A28

Description

The panel has a rough appearance. Rooting vegetation removed from along the seams. Significant spalled sections of concrete observed along the bottom right-hand corner (app. 2 meters wide) and in a central location along the top seam of the panel. A scrub tree found growing over the keywall was cut down and the stump removed. Some minor spalling of concrete observed in the top right-hand corner of the panel.

CAP SECTION LOCATION: Panel A29

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough appearance. Rooting vegetation removed from along the seams. Some minor spalling of concrete observed in the left-hand corner, and along the top seam, of the panel.

CAP SECTION LOCATION: Panel A30

Description

No significant or obvious interior cracks extending across the top of the panel. Minor spalling of concrete observed in the top and bottom left-hand corners, and in the bottom right-hand corner, of the panel.

CAP SECTION LOCATION: Panel A31

Description

The panel has a rough and weathered appearance. Rooting vegetation removed from along the seams. Some cracks observed in the lower left-hand corner with minor spalling of concrete in the top right-hand corner of the panel. There is significant spalling and cracks (extending more than 2 meters) appearing in the concrete along the bottom seam adjacent to keywall on the right side of the panel.

CAP SECTION LOCATION: Panel A32

Description

The panel has a relatively rough appearance. Rooting vegetation removed from along the seams. Some spalling of concrete observed in the lower left-hand corner with chipped out sections to a depth of around 10 centimeters. Also, there was some minor spalling of concrete observed along the top seam and in the upper right-hand corner of the panel. Several cracks were also observed in the keywall.

CAP SECTION LOCATION: Panel A33

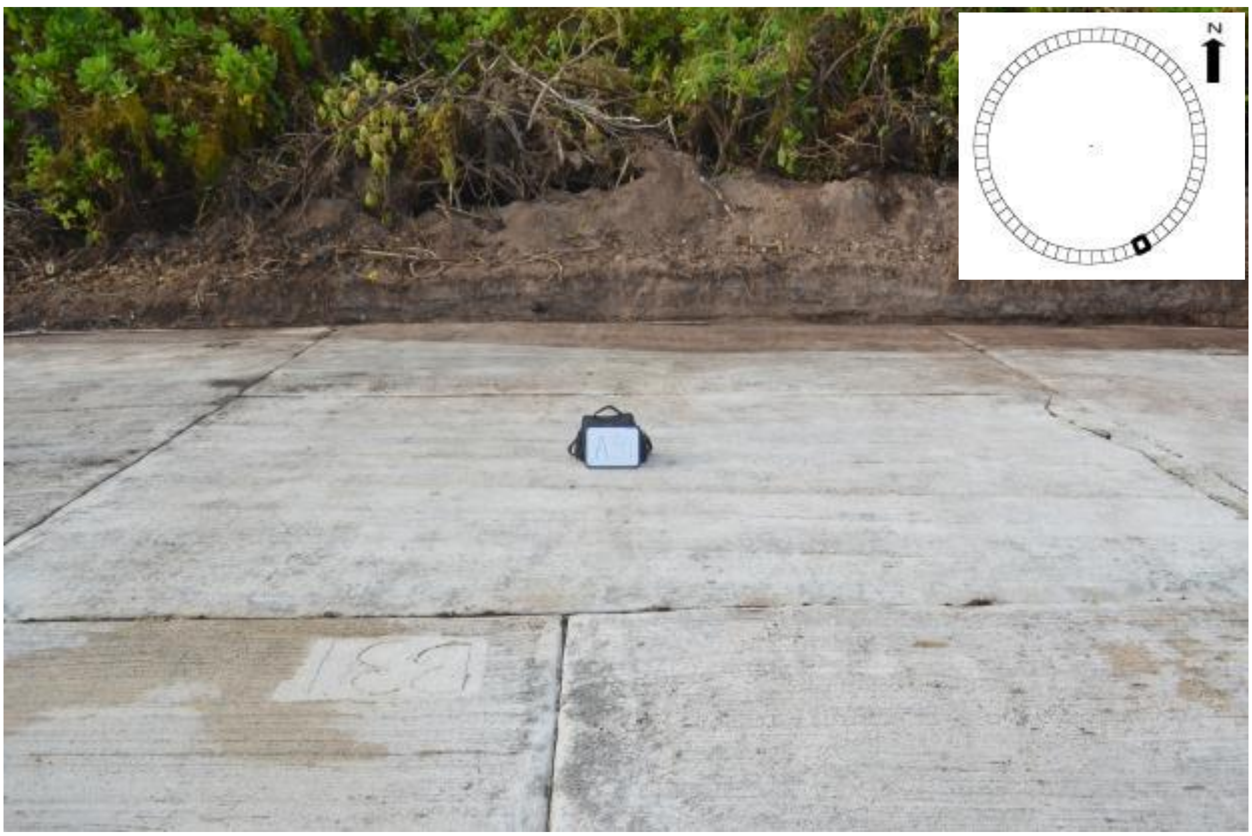
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough and weathered appearance. Rooting vegetation removed from along the seams.

CAP SECTION LOCATION: Panel A34

Description

A crack observed in the concrete extending down from the top of the panel – located about 20 to 25 centimeters inside the left edge of the panel and intersecting with the seam about half way down the panel.



CAP SECTION LOCATION: Panel A35

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel A36

Description

The panel has a relatively rough and weathered appearance. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed in the top left-hand corner, and along the top left seam, of the panel.

CAP SECTION LOCATION: Panel A37

Description

The panel has a relatively rough and weathered appearance. Some minor spalling of concrete observed along the upper right seam of the panel. Significant spalling of concrete observed in the lower left-hand corner of the panel with the chipped out section extending more than 1 meter along the seam. Panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel A38

Description

The panel has a relatively rough and weathered appearance. A crack with spalled edges observed in the lower right-hand corner of the panel extending up about 20 to 25 centimeters inside the seam for a distance of about 1 meter.

CAP SECTION LOCATION: Panel A39

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough and weathered appearance. Minor spalling observed in the upper left-hand corner of the panel.

CAP SECTION LOCATION: Panel A40

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough and more weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel A41

Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a slightly more rough and weathered appearance. Minor spalling of concrete observed in the upper left-hand corner of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel A42

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough and more weathered appearance. There is an indication from the GPR data that some areas under the panel are poorly supported or “voided”.

CAP SECTION LOCATION: Panel A43

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough and weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel A44

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough and more weathered appearance. Rooting vegetation removed from along the panel seams..

CAP SECTION LOCATION: Panel A45

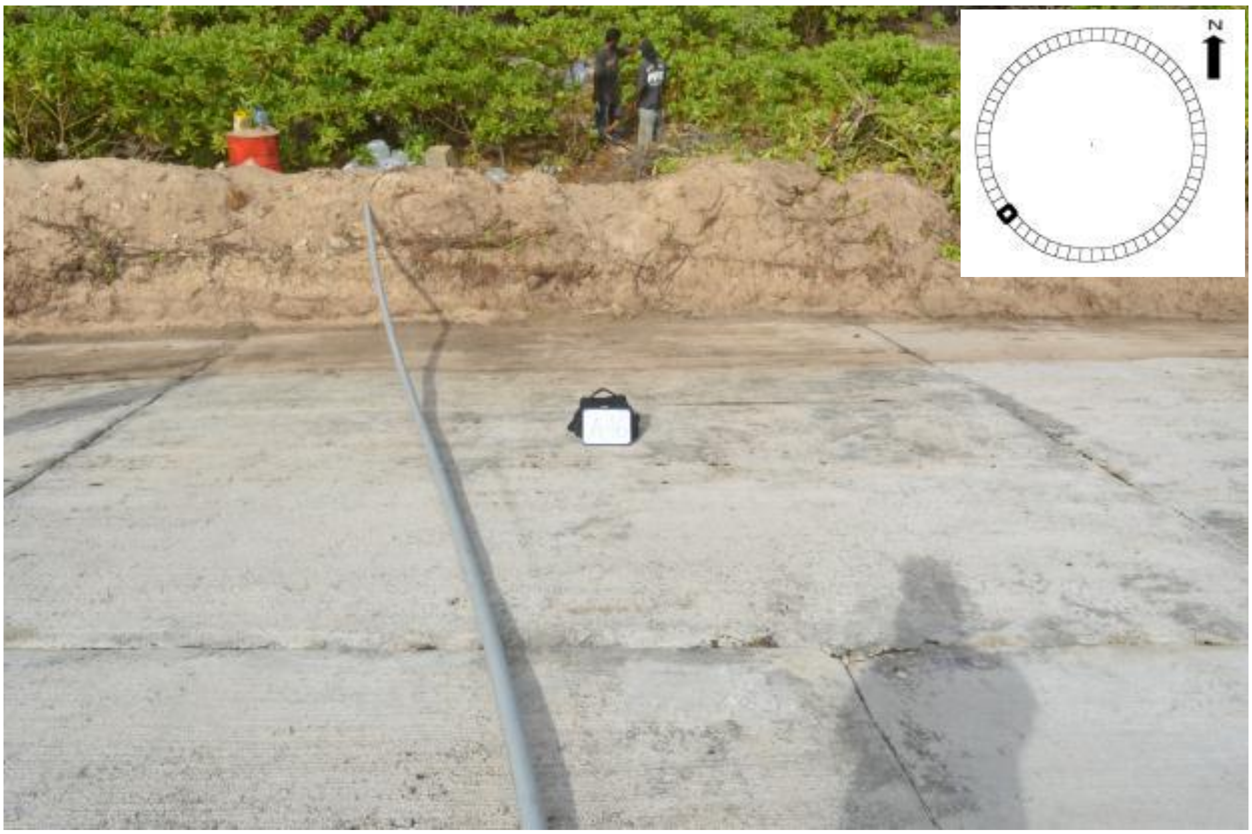
Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. There is indication from the GPR data that some areas under the panel are poorly supported or "voided".

CAP SECTION LOCATION: Panel A46

Description

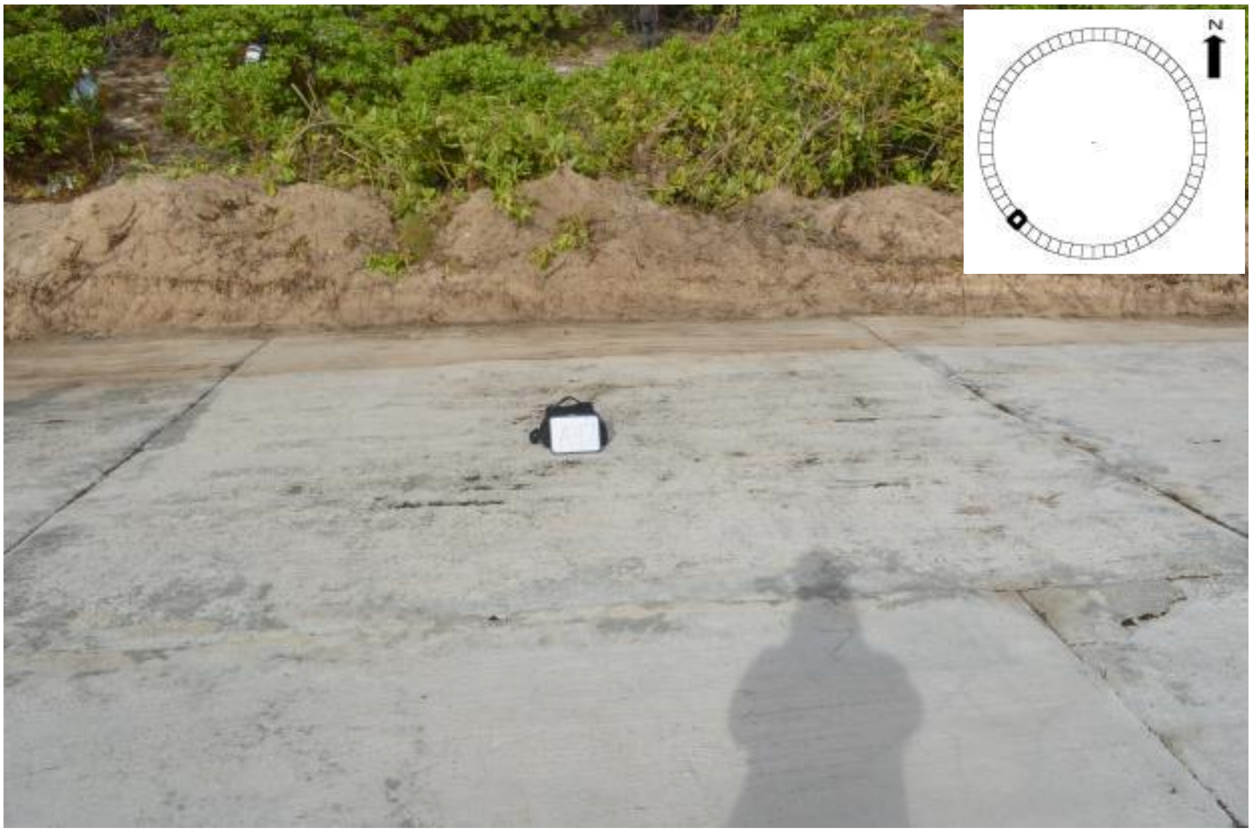
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel A47

Description

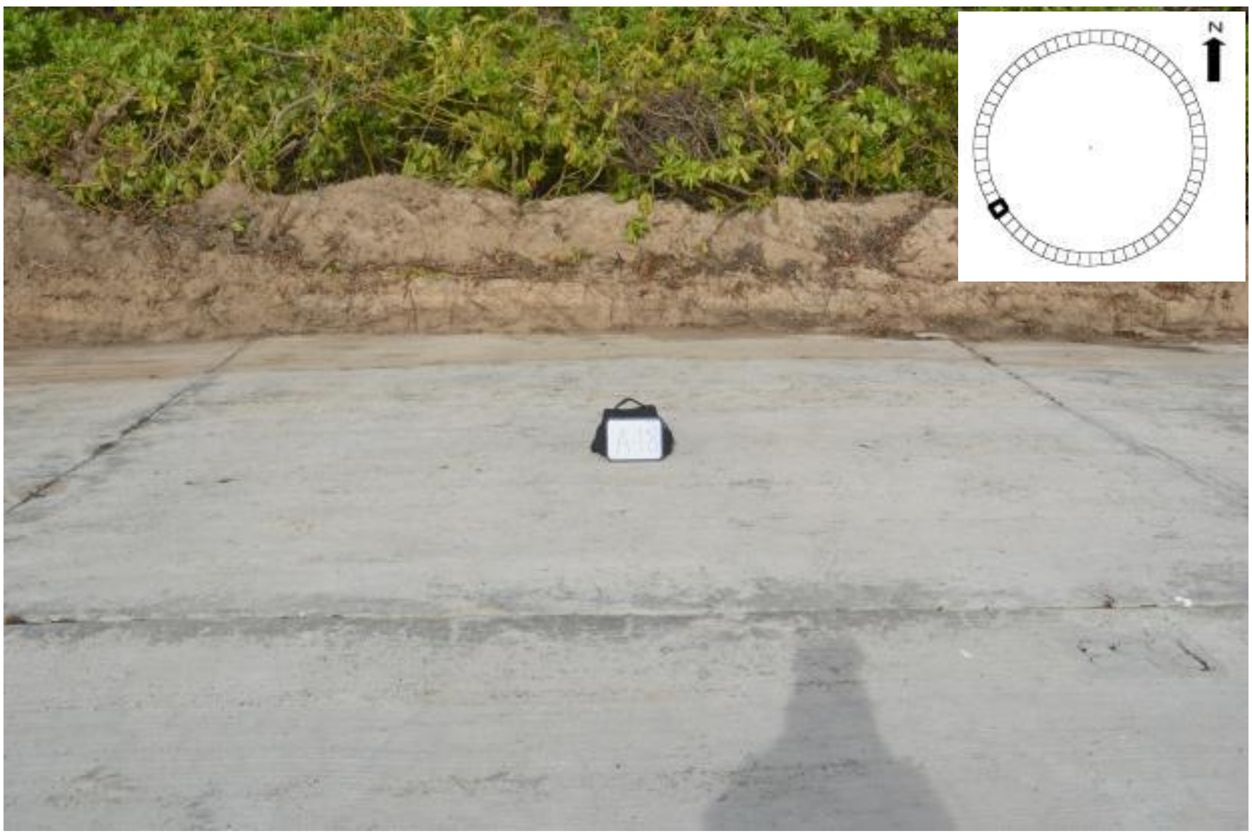
No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel A48

Description

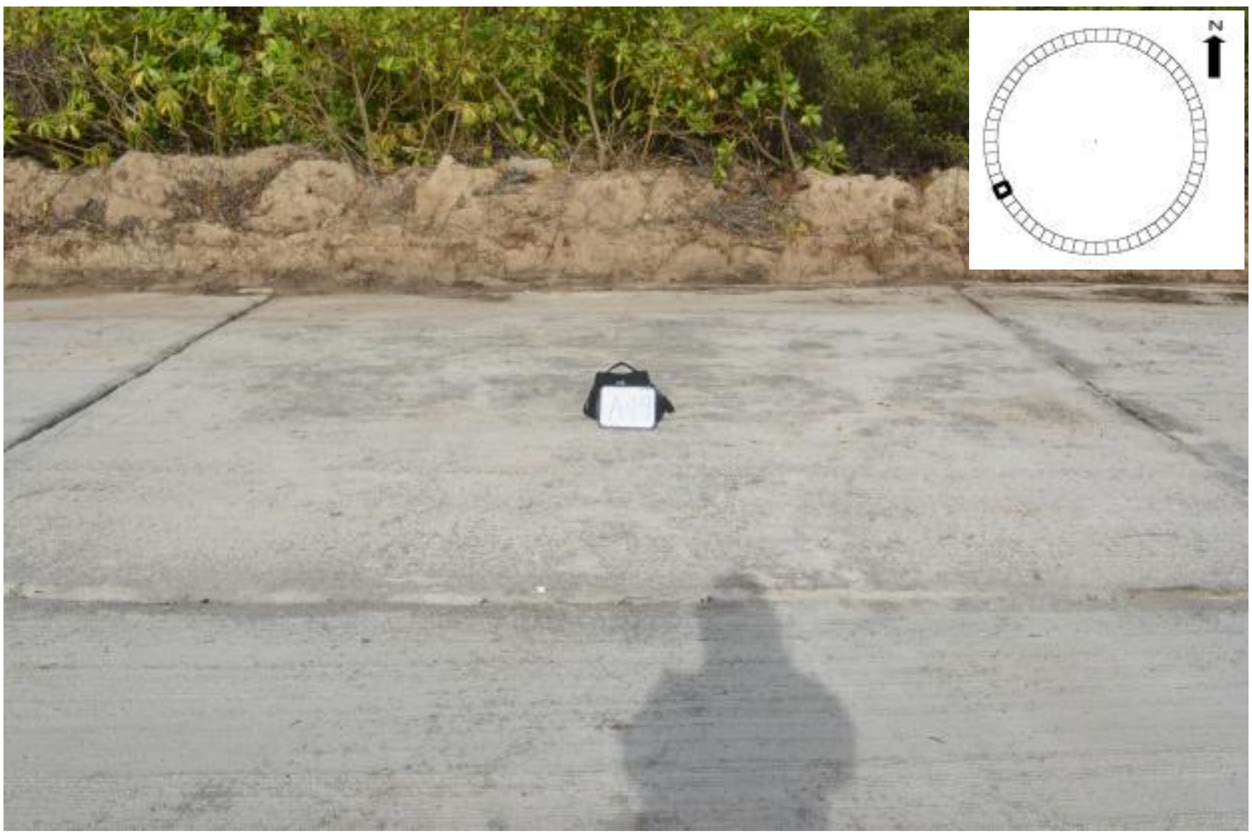
No significant or obvious interior cracks extending across the top of the panel. Spalling/cracked concrete observed in the lower left-hand corner of the panel, and on the keywall.



CAP SECTION LOCATION: Panel A49

Description

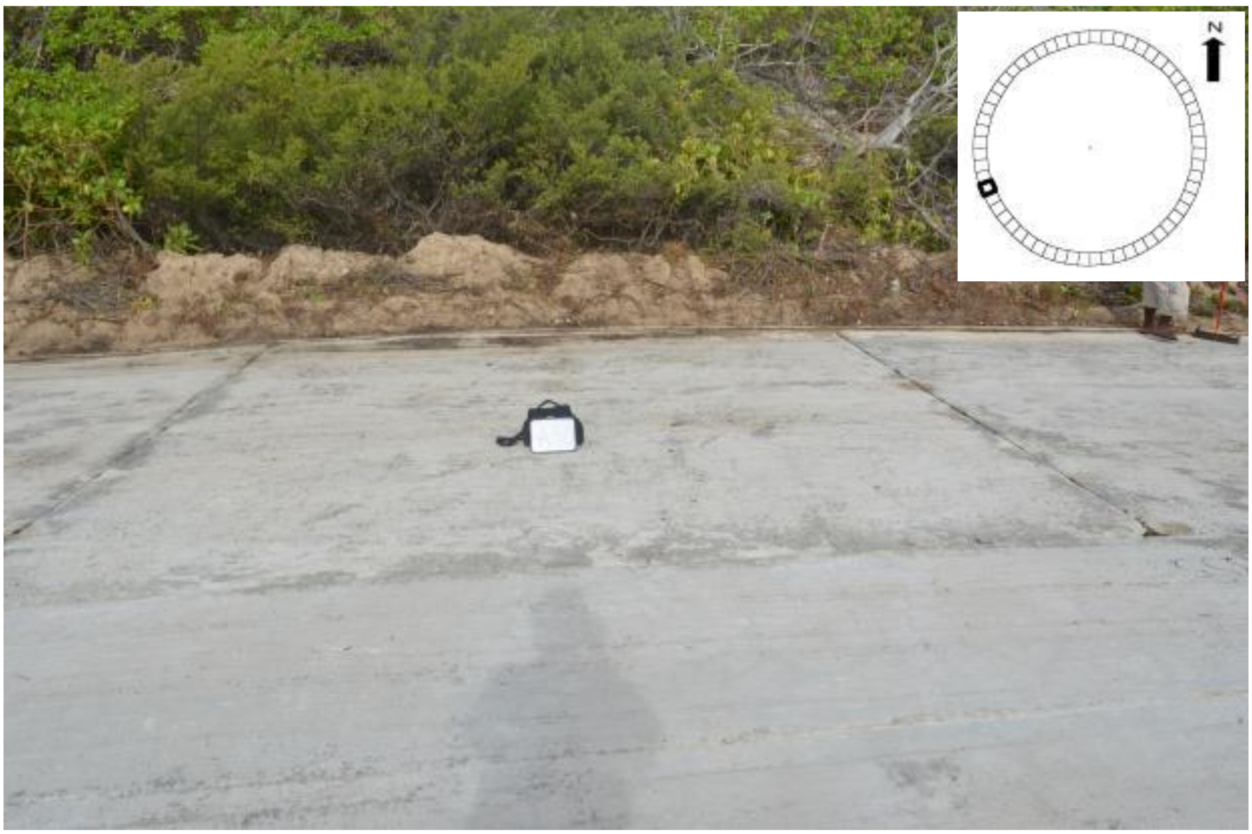
No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel A50

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some spalling/chipping of concrete observed in the upper left and right-hand corners of the panel.



CAP SECTION LOCATION: Panel A51

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams. Some minor spalling/chipping of concrete observed in the upper right-hand corner of the panel, and along the panel seams.

CAP SECTION LOCATION: Panel A52

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams. Some minor spalling with small chipped out pieces of concrete observed along the left side of the top seam.

CAP SECTION LOCATION: Panel A53

Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams. Panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel A54

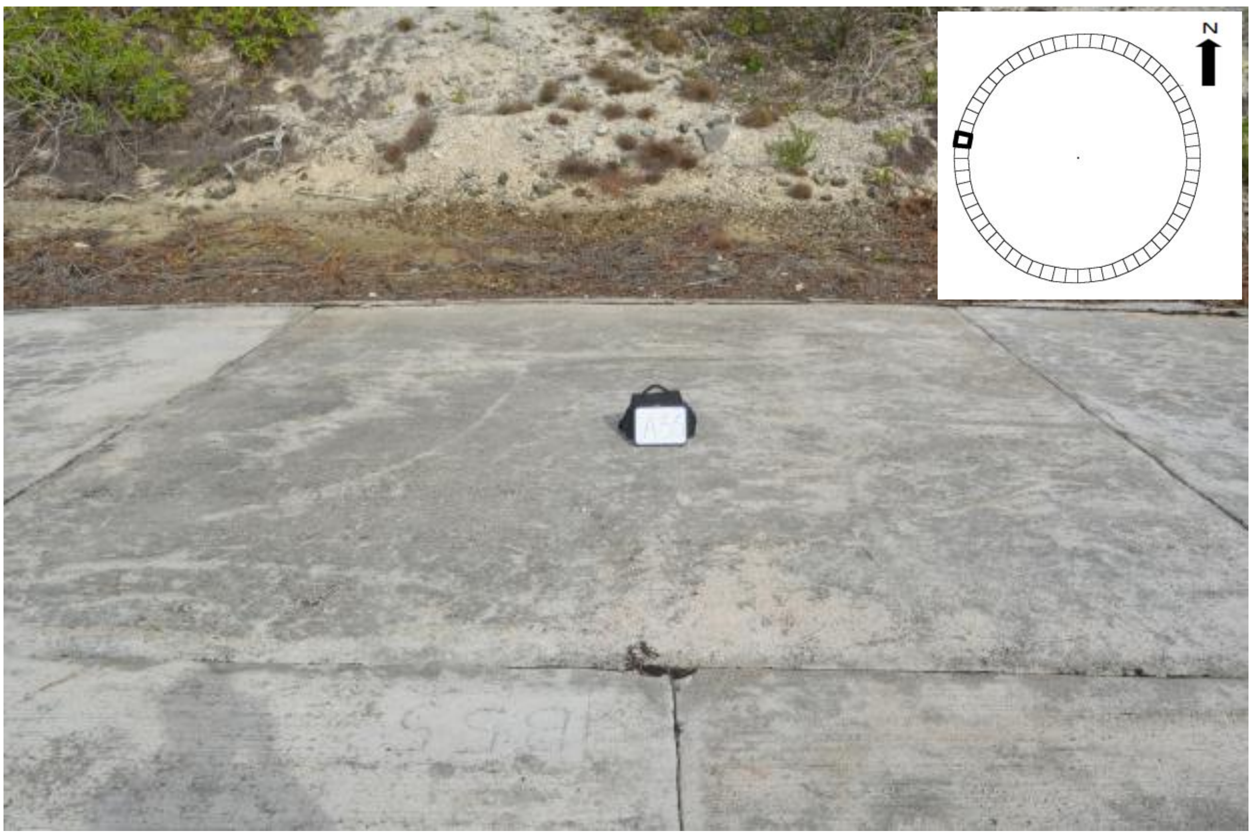
Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams. Rooting vines appear to have caused some spalling/cracking of concrete in the upper left-hand corner. Panel contains a capped concrete bore-hole (CD-18) from the 1980 NAS investigation.

CAP SECTION LOCATION: Panel A55

Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams. Rooting vines appear to have caused some spalling/cracking of concrete in the upper right corner. Significant spalling of concrete appearing along the right bottom seam (chipped section is about 1.2 meters in length) adjacent to the keywall.



CAP SECTION LOCATION: Panel A56

Description

Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed along the top seam with the chipped out section extending down about half the depth of the panel cap. More significant spalling/chipping of concrete along the bottom seam adjacent to the keywall about 2 meters distance from the left edge of the panel.

CAP SECTION LOCATION: Panel A57

Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel A58

Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams. Some spalling of concrete observed along the bottom seam adjacent to the keywall, and in the top right-hand corner of the panel.

CAP SECTION LOCATION: Panel A59

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed in the upper left-hand corner of the panel.

CAP SECTION LOCATION: Panel A60

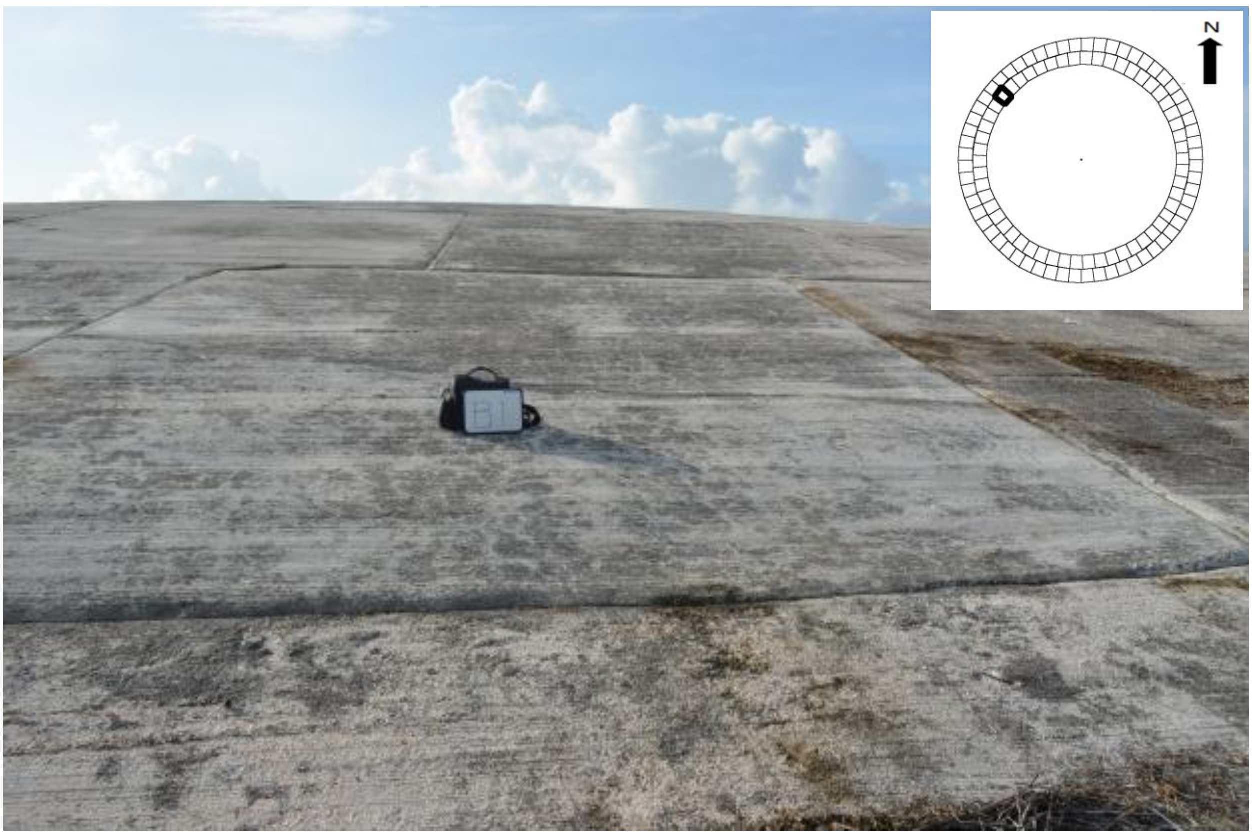
Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some very minor spalling of concrete observed in the lower right-hand corner of the panel.

CAP SECTION LOCATION: Panel B1

Description

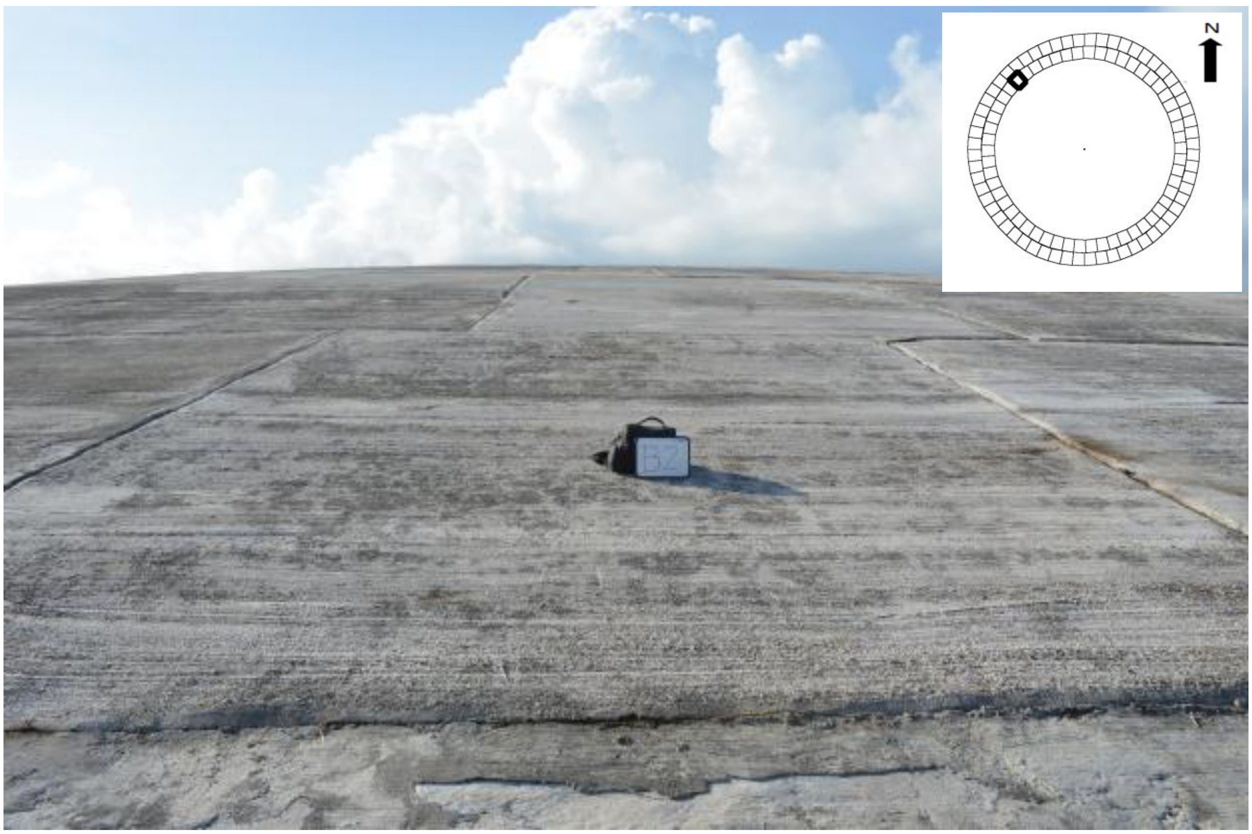
Significant spalling of concrete observed in upper right corner where the chipped out piece of concrete extends down to contaminated soil – cement grout waste pile mixture below. Surface crack observed running across the full width of the panel at a mid-point up the segment. Rooting vegetation removed from along the panel seams. Panel recommended for priority repair.



CAP SECTION LOCATION: Panel B2

Description

A obvious crack observed running across the full width of the panel in the upper portion of the segment. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B3

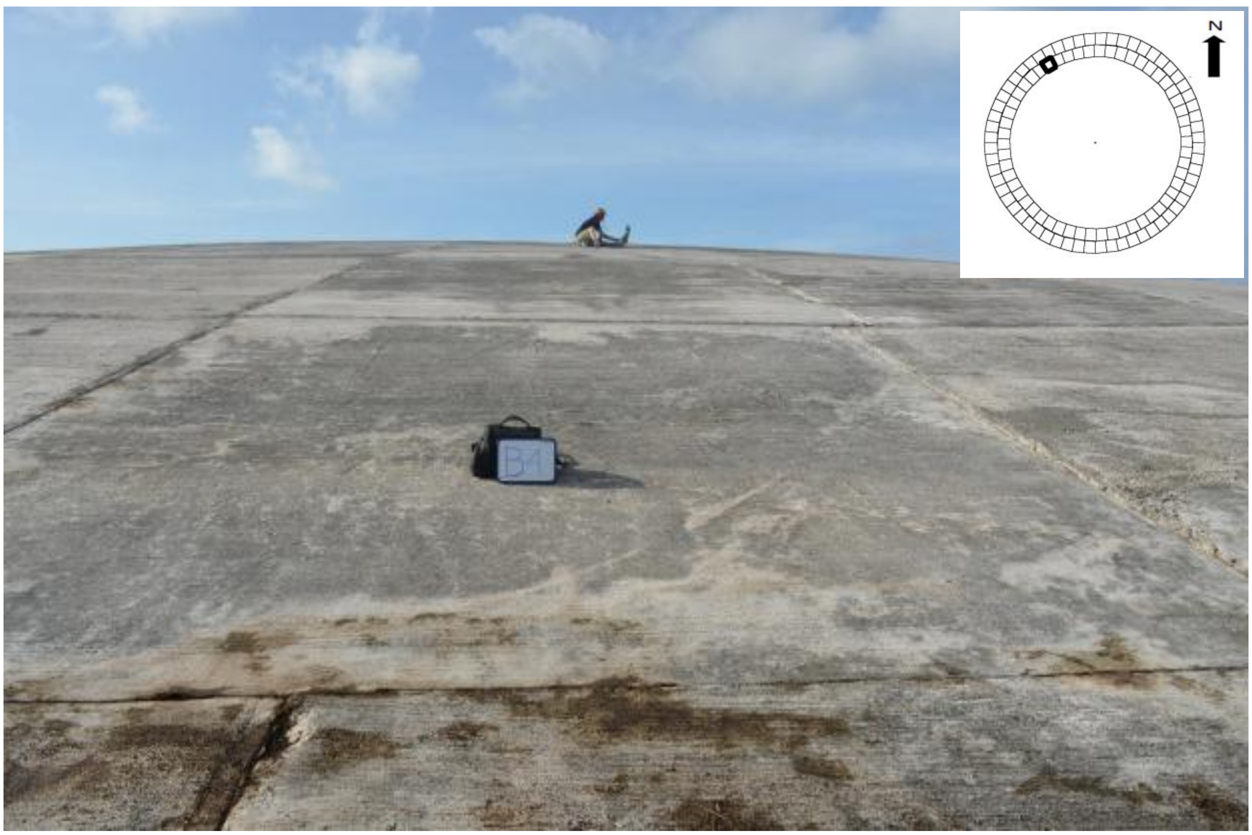
Description

A crack observed extending up from a mid-point along the bottom seam of the panel branching into a fork at a mid-point up the segment. The panel has a relatively dark and weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel B4

Description

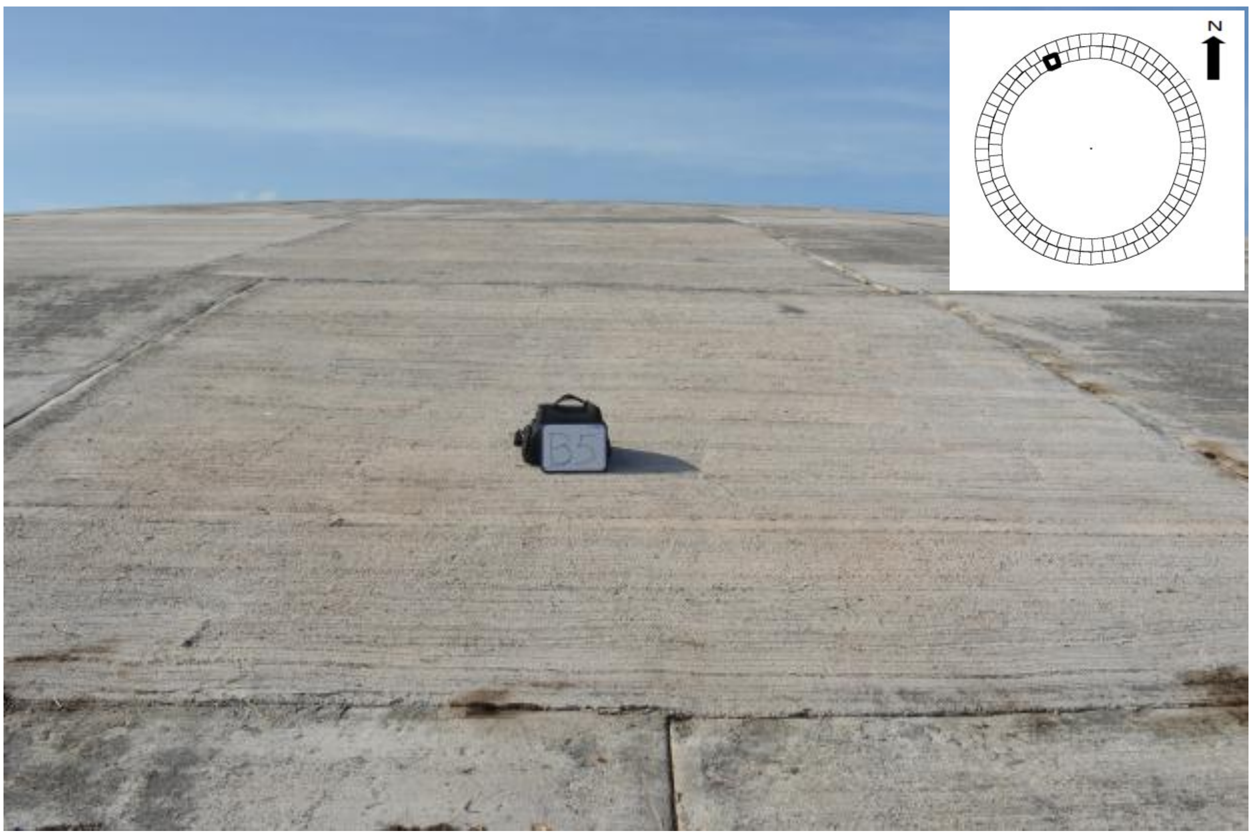
No significant or obvious interior cracks extending across the top of the panel. The panel appears dark and weathered. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B5

Description

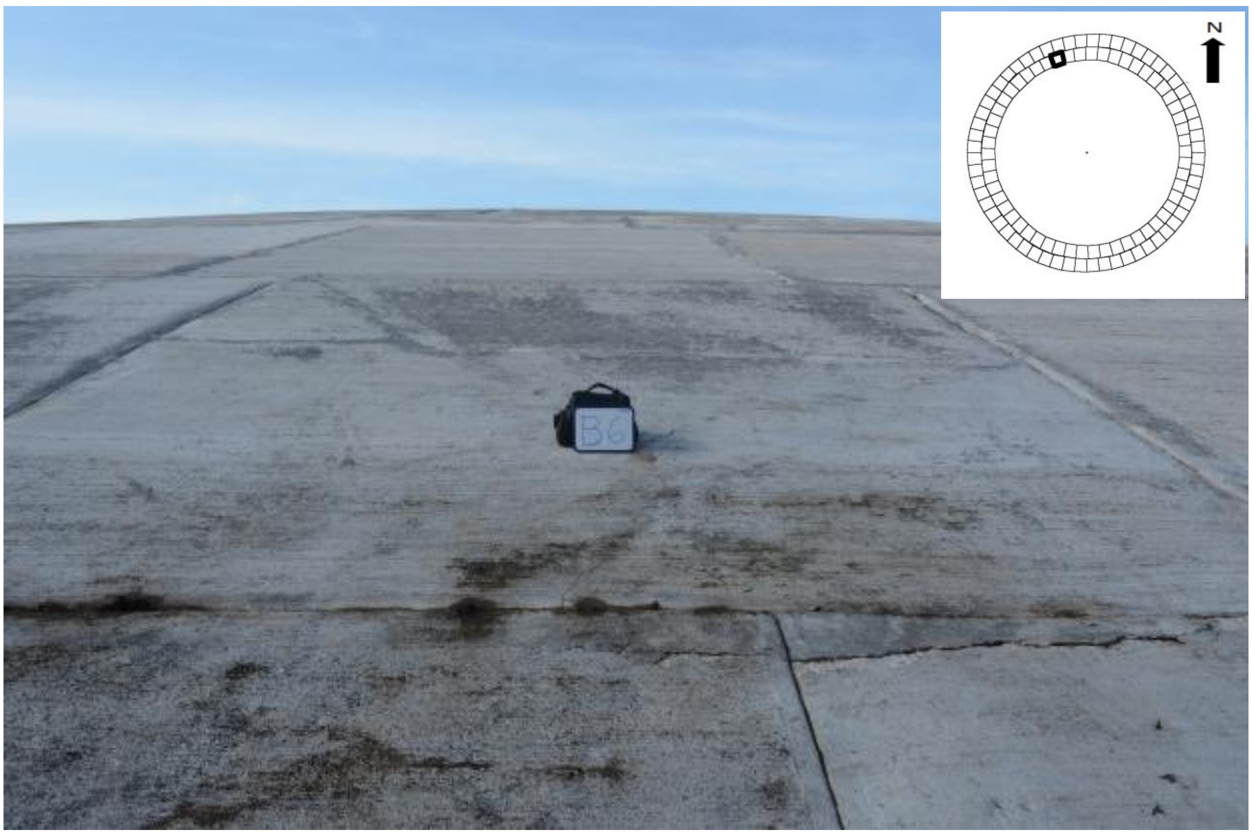
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B6

Description

A crack observed extending up about 1.5 meters from a mid-point along the bottom seam of the panel and branching out to the left and right. The right fork intersects the right edge at a mid-point up the panel while the left fork extends up towards the upper left-hand corner. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B7

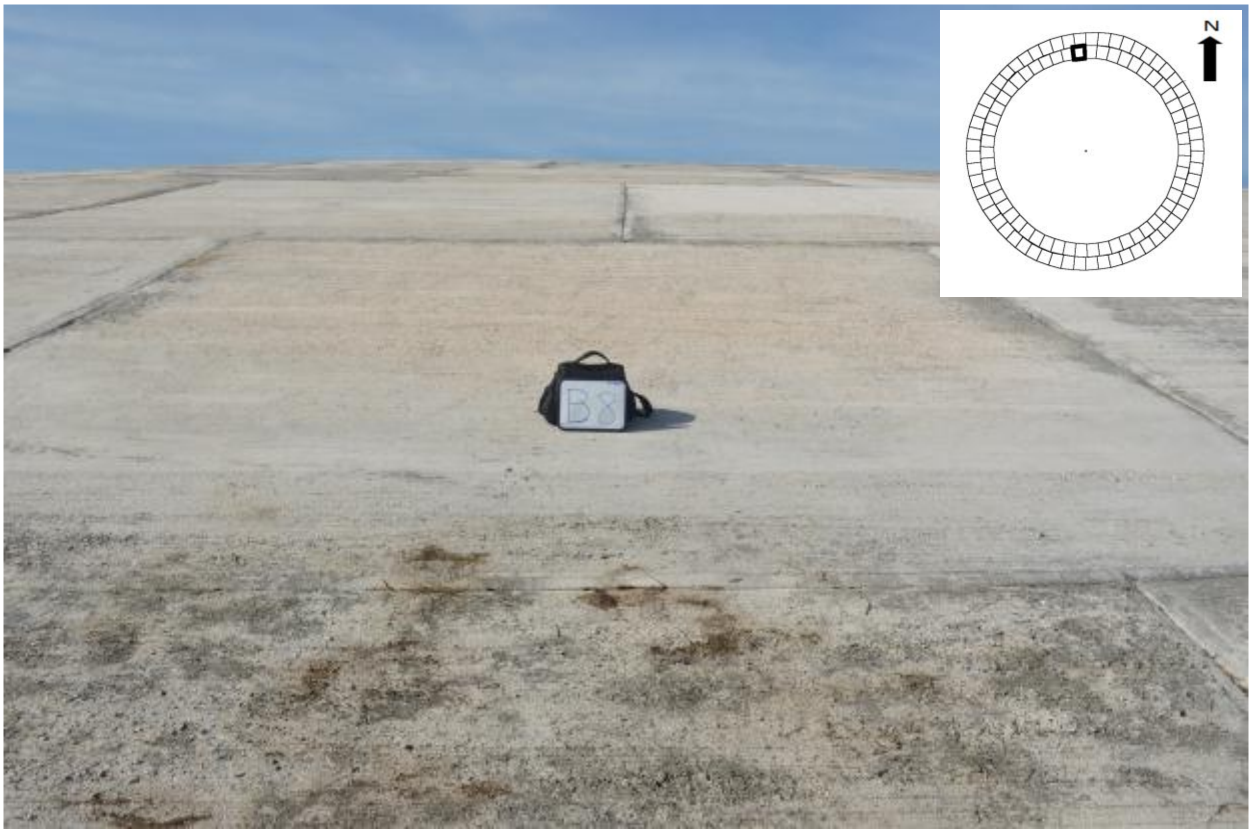
Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel B8

Description

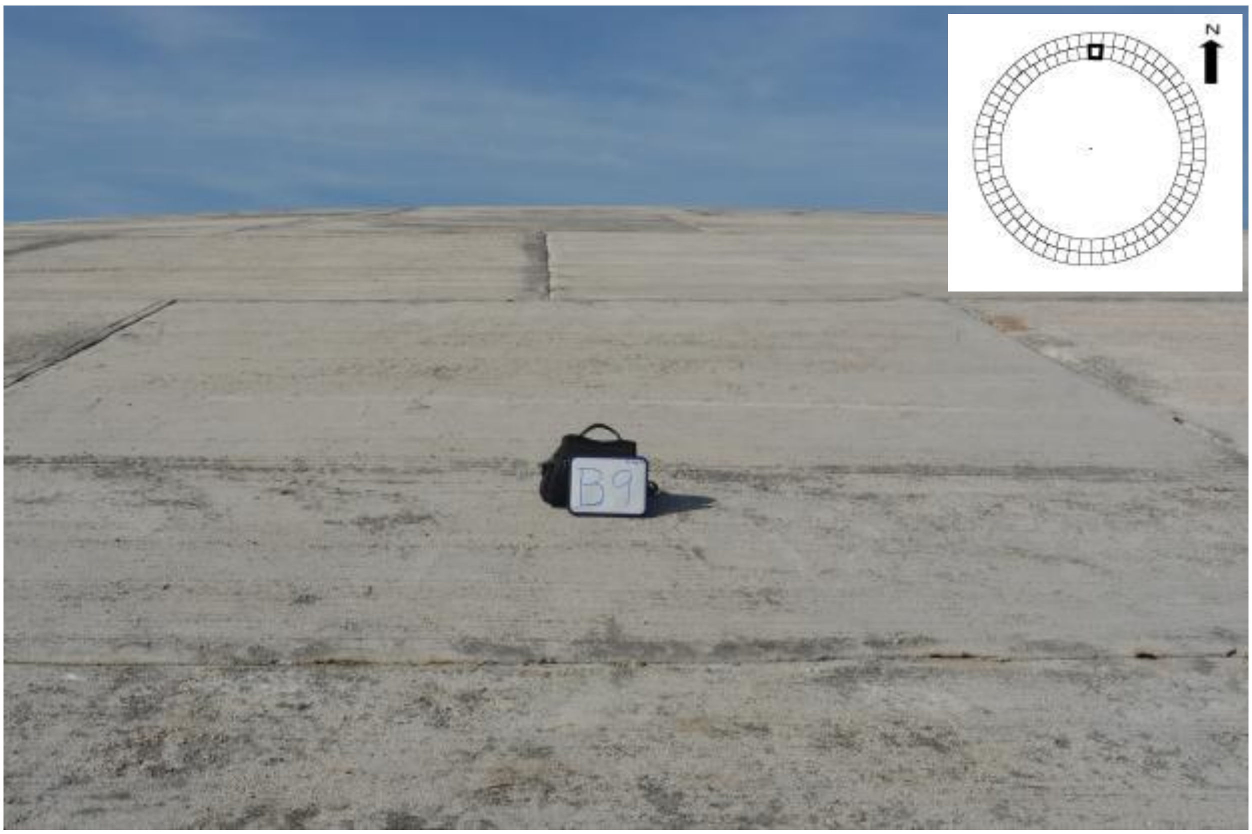
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B9

Description

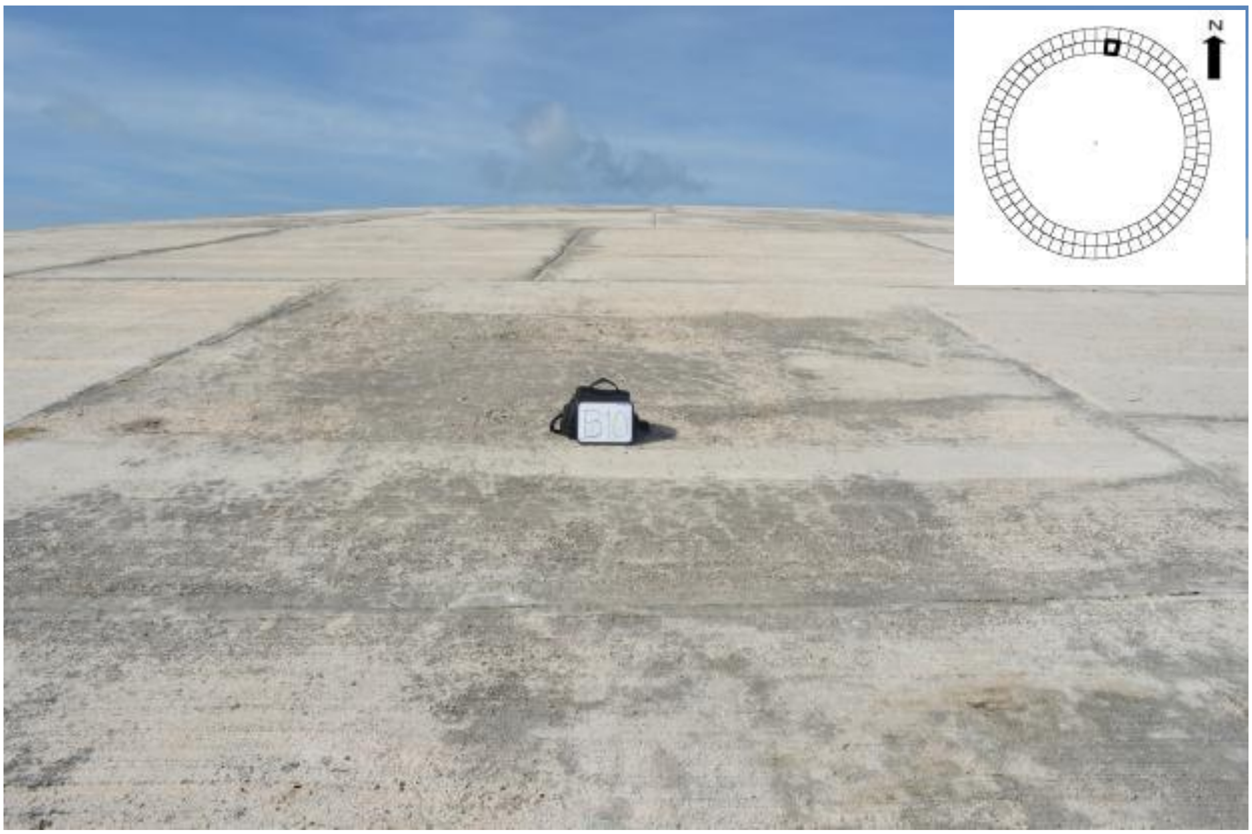
Rooting vegetation removed from along the panel seams. No significant or obvious interior cracks extending across the top of the panel.



CAP SECTION LOCATION: Panel B10

Description

No significant or obvious interior cracks extending across the top of the panel. Panel appears rough and weathered. There appears to be deeper and more obvious cracks appearing along the seams compared with those appearing around adjoining panels. Some minor spalling of concrete observed along the bottom left seam at intersection corner with panel A9/A10.



CAP SECTION LOCATION: Panel B11

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel B12

Description

Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed along the bottom seam of the panel. A surface crack can be seen running across the segment at a mid-point up the panel.

CAP SECTION LOCATION: Panel B13

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel B14

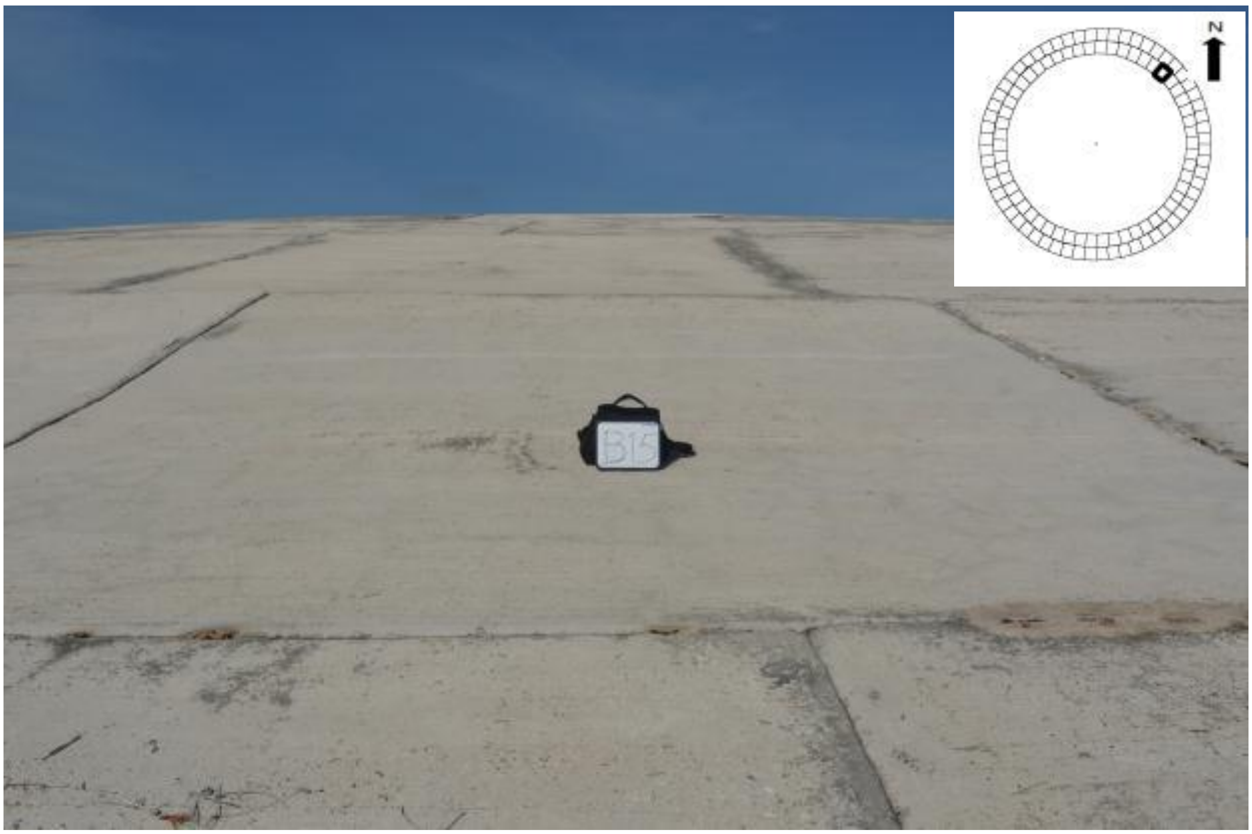
Description

Obvious spalling of concrete observed in the bottom left-hand corner of the panel. Rooting vegetation removed from along the panel seams. A surface crack can also be seen extending up from the bottom seam intersection with other surface cracks branching to the left and right side at a mid-point up the panel.

CAP SECTION LOCATION: Panel B15

Description

No significant or obvious interior cracks extending across the top of the panel. Minor spalling of concrete observed along the bottom seam of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B16

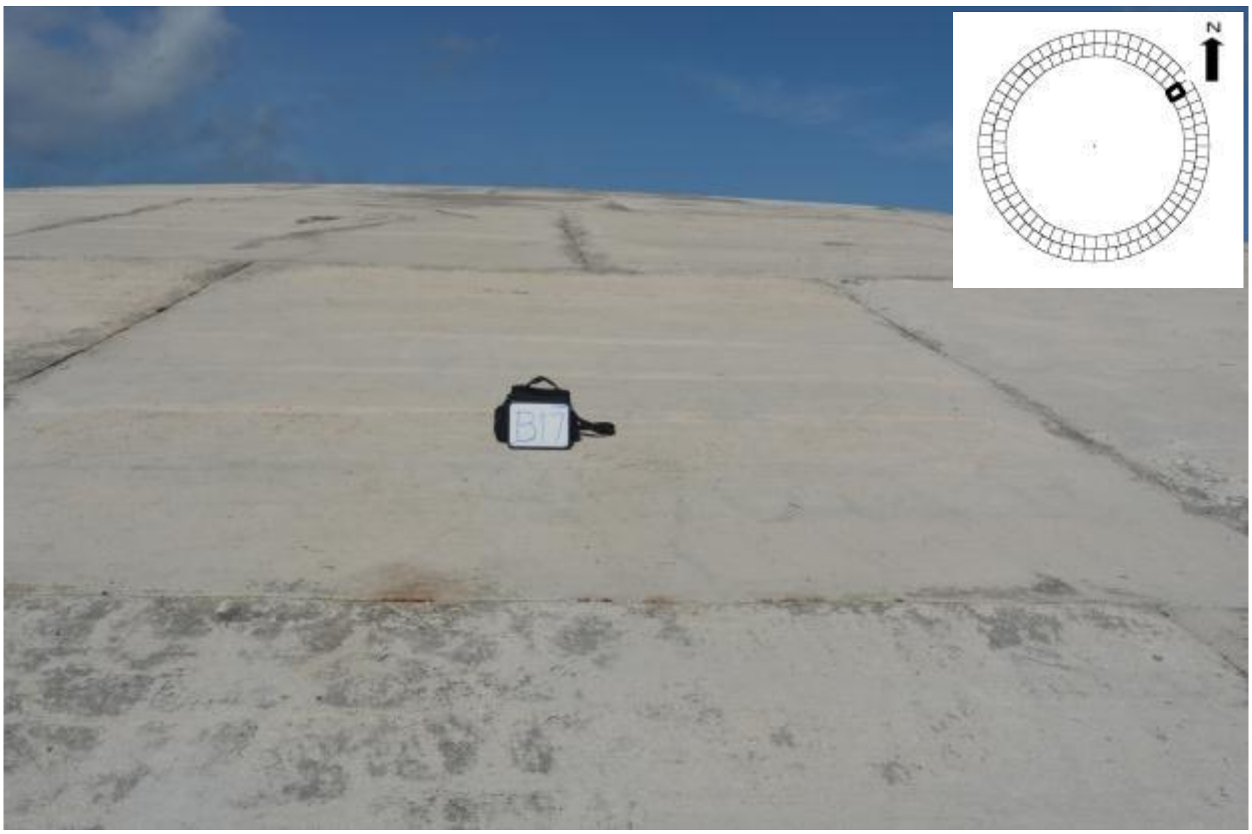
Description

No significant or obvious interior cracks extending across the top of the panel. Some minor spalling of concrete observed in the upper right-hand corner of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel B17

Description

No significant or obvious interior cracks extending across the top of the panel. Minor spalling of concrete observed in the lower right-hand corner of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B18

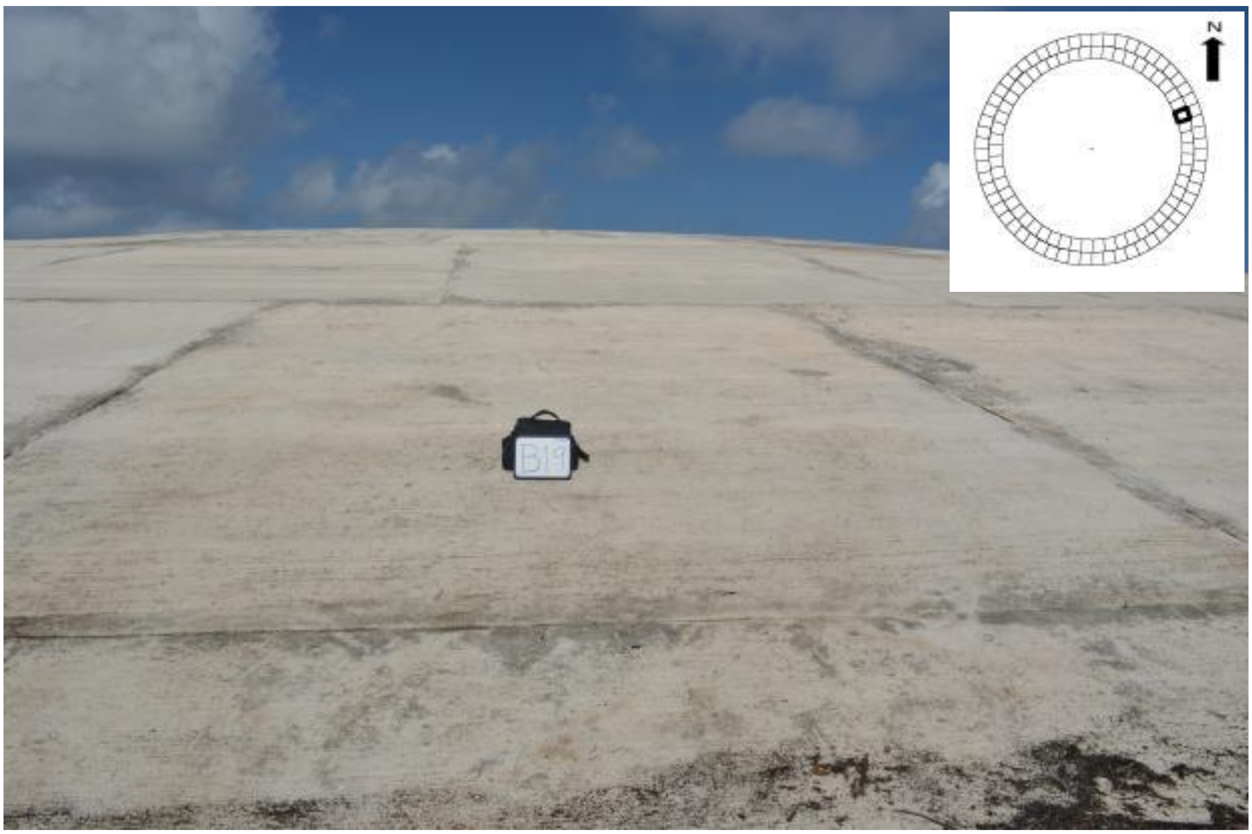
Description

No significant or obvious interior cracks extending across the top of the panel. Some minor spalling of concrete observed in the upper left-hand corner of the panel, and along the bottom seam overhanging panel A19. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel B19

Description

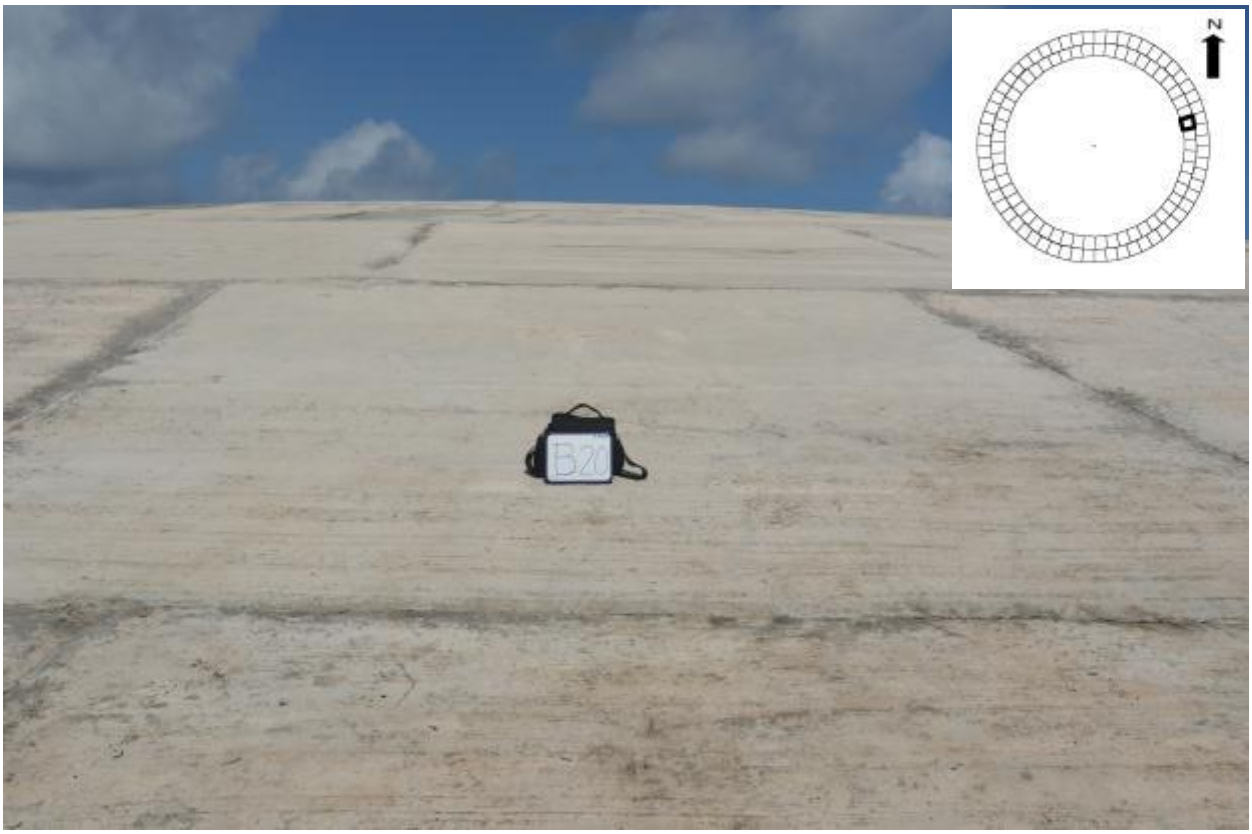
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B20

Description

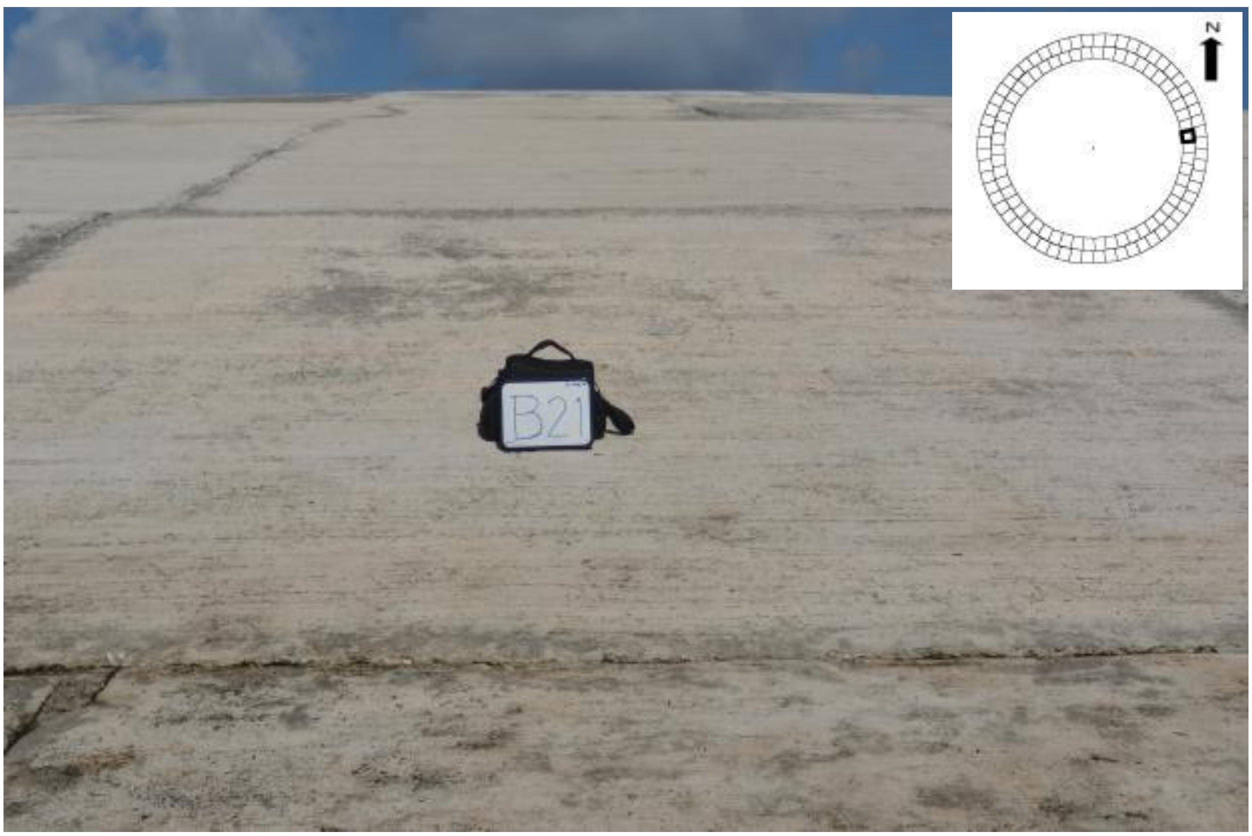
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B21

Description

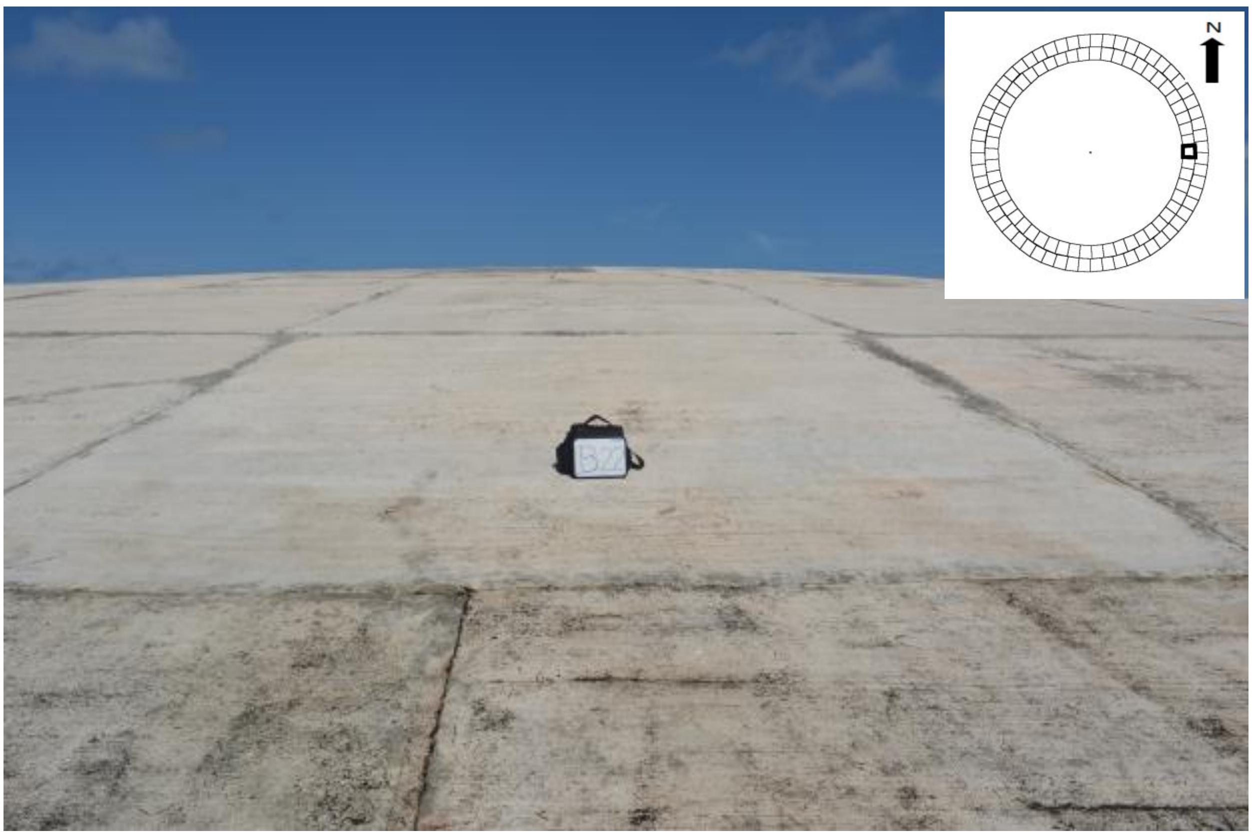
No significant or obvious interior cracks extending across the top of the panel. Some minor spalling of concrete observed along the bottom seam overhanging the A panel below. Panel contains a filled concrete bore-hole (CD-3) from the 1980 NAS investigation.



CAP SECTION LOCATION: Panel B22

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete in the bottom left-hand corner of the panel, and along the bottom seam at intersecting corner of the A panels below.



CAP SECTION LOCATION: Panel B23

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. There is some minor spalling of concrete in the upper left corner of the panel. There appears to be deeper and more obvious cracks running along the seam joints compared with those observed on adjacent panels.

CAP SECTION LOCATION: Panel B24

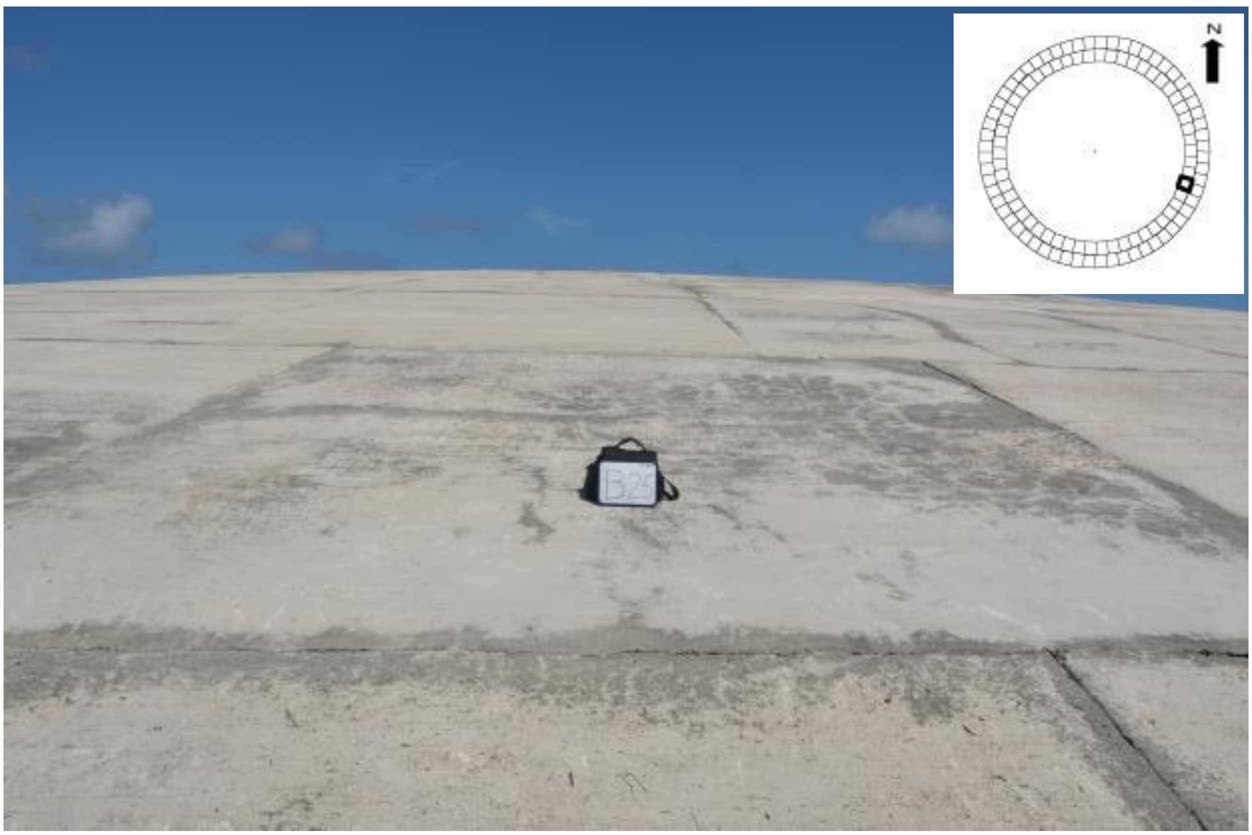
Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel B25

Description

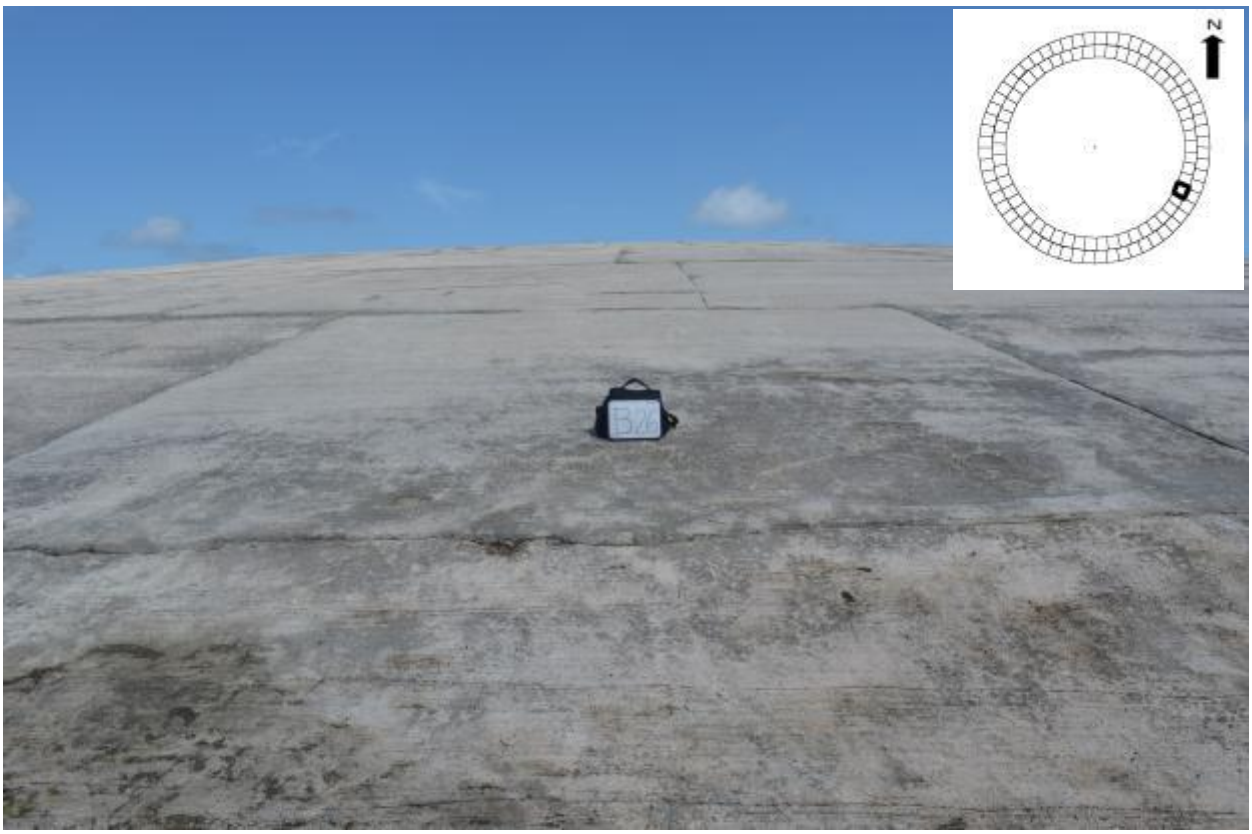
No significant or obvious interior cracks extending across the top of the panel. The panel appears rough and weathered. There is some minor spalling of concrete along the bottom seam. There also appears to be deeper and more obvious cracks running along the seam joints compared with those appearing around the majority of panels.



CAP SECTION LOCATION: Panel B26

Description

No significant or obvious interior cracks extending across the top of the panel. The panel appears to have a dark and weathered appearance. There is some minor spalling of concrete along the bottom seam. There appears to be deeper and more obvious cracks running along the seam joints compared this those appearing around the majority of panels.



CAP SECTION LOCATION: Panel B27

Description

No significant or obvious interior cracks extending across the top of the panel. The panel appears to have a dark and weathered appearance. There is some minor spalling of concrete in the lower and upper left-hand corners of the panel. There also appears to be deeper and more obvious cracks running along the seam joints compared with those appearing around the majority of panels.

CAP SECTION LOCATION: Panel B28

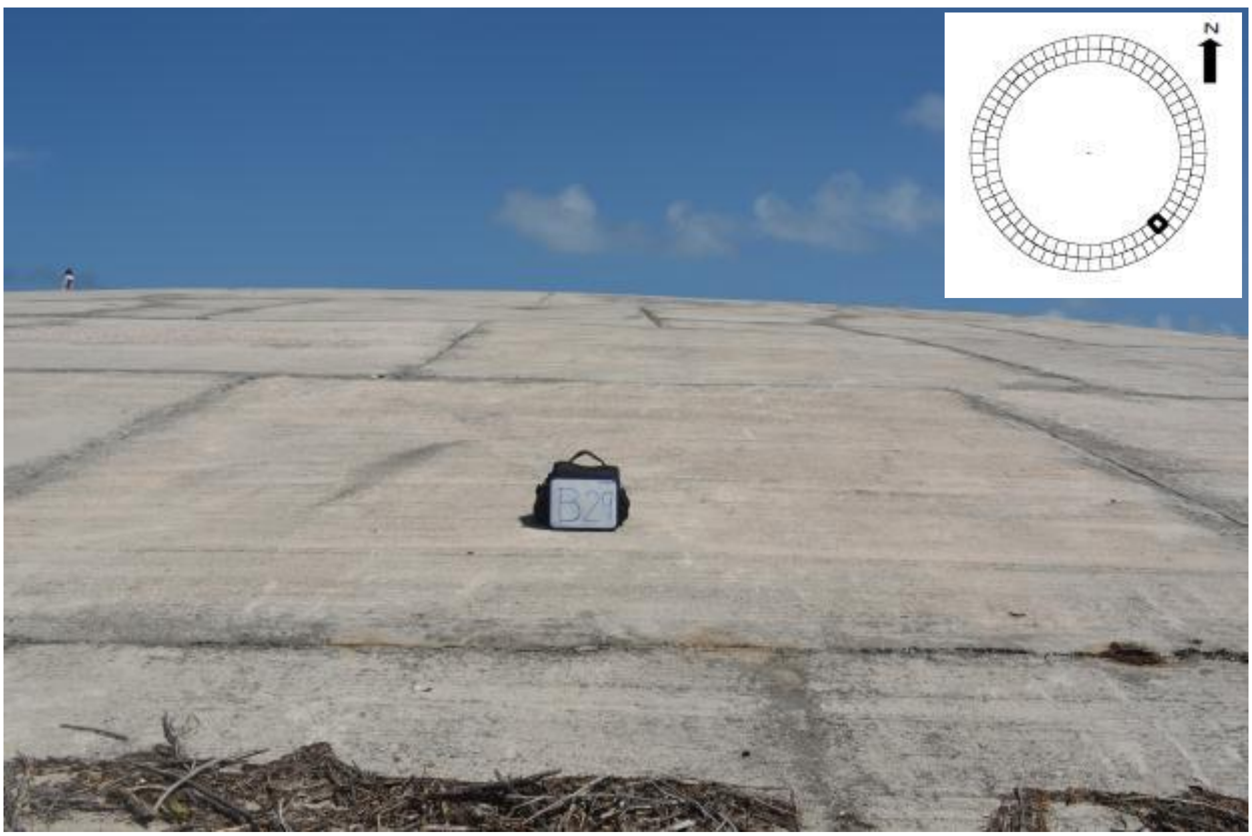
Description

No significant or obvious interior cracks extending across the top of the panel. The panel appears to have a relatively rough appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel B29

Description

No significant or obvious interior cracks extending across the top of the panel. The panel appears to have a relatively rough appearance. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed along the bottom left seam overhanging the A panel below.



CAP SECTION LOCATION: Panel B30

Description

No significant or obvious interior cracks extending across the top of the panel. The upper portion of the panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed in the upper left-hand corner of the panel, and along the bottom seam overhanging the A panel below.

CAP SECTION LOCATION: Panel B31

Description

No significant or obvious interior cracks extending across the top of the panel. The panel appears to have a relatively rough appearance. Rooting vegetation removed from along the panel seams. Some spalling/chipping of concrete observed in the upper right-hand corner of the panel.

CAP SECTION LOCATION: Panel B32

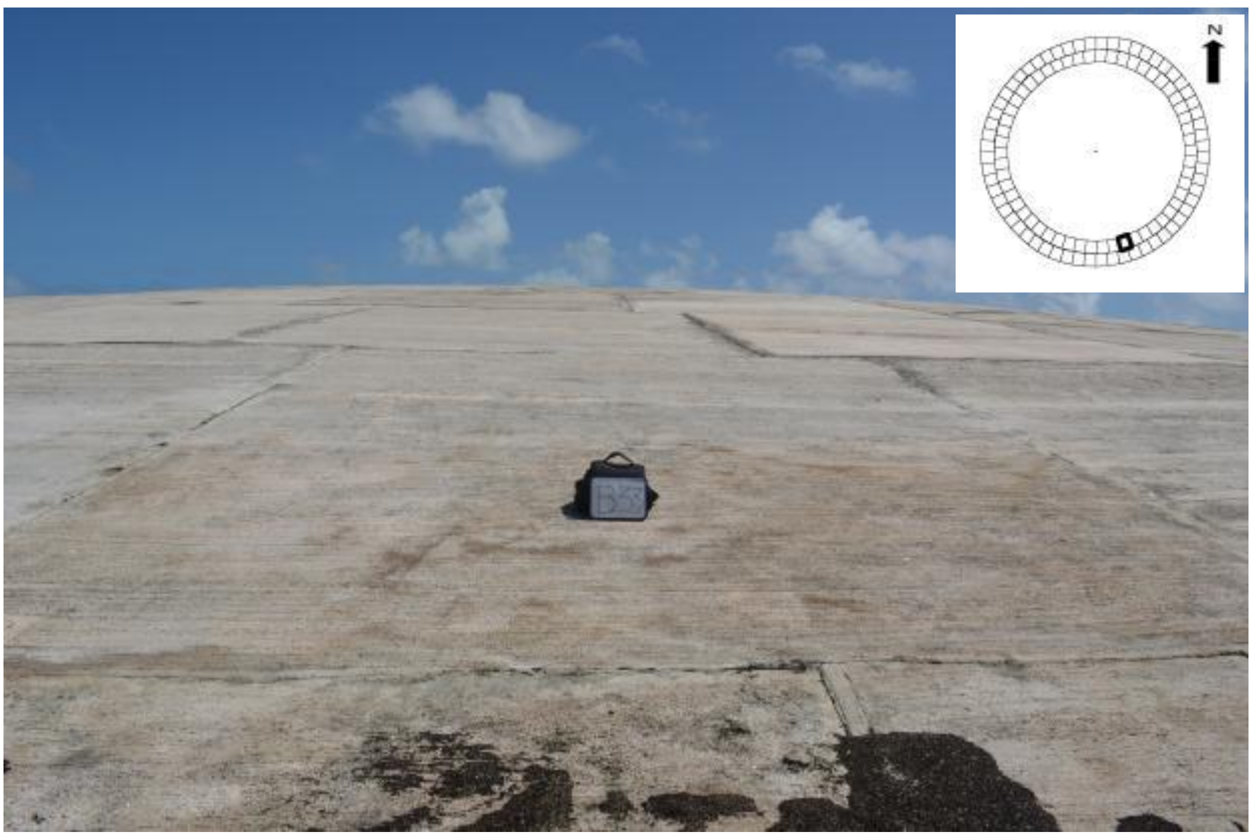
Description

No significant or obvious interior cracks extending across the top of the panel. The upper section of the panel has a relatively rough appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel 33

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Some minor spalling of concrete observed in the upper left-hand corner of the panel, and along the bottom left seam adjacent to the intersecting corners between the A panels below.



CAP SECTION LOCATION: Panel B34

Description

No significant or obvious interior cracks extending across the top of the panel. The upper portion of the panel appears to have a relatively rough appearance. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed along the upper seam of the panel.

CAP SECTION LOCATION: Panel B35

Description

No significant or obvious interior cracks extending across the top of the panel. The upper portion of the panel appears to have a relatively rough appearance. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed along the bottom seam adjacent to the intersecting corner of the A panels below.

CAP SECTION LOCATION: Panel B36

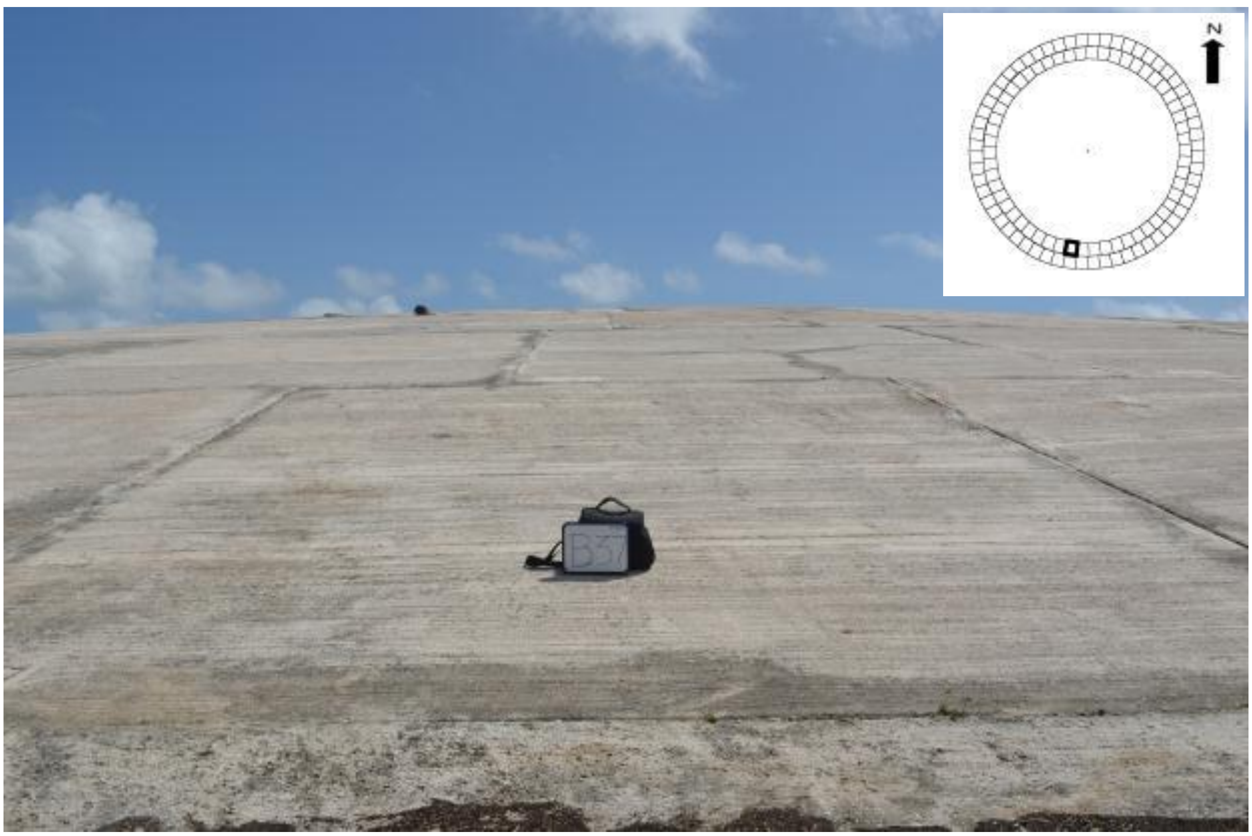
Description

No significant or obvious interior cracks extending across the top of the panel. The panel appears to have a relatively rough appearance. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed along the bottom seam of the panel.

CAP SECTION LOCATION: Panel B37

Description

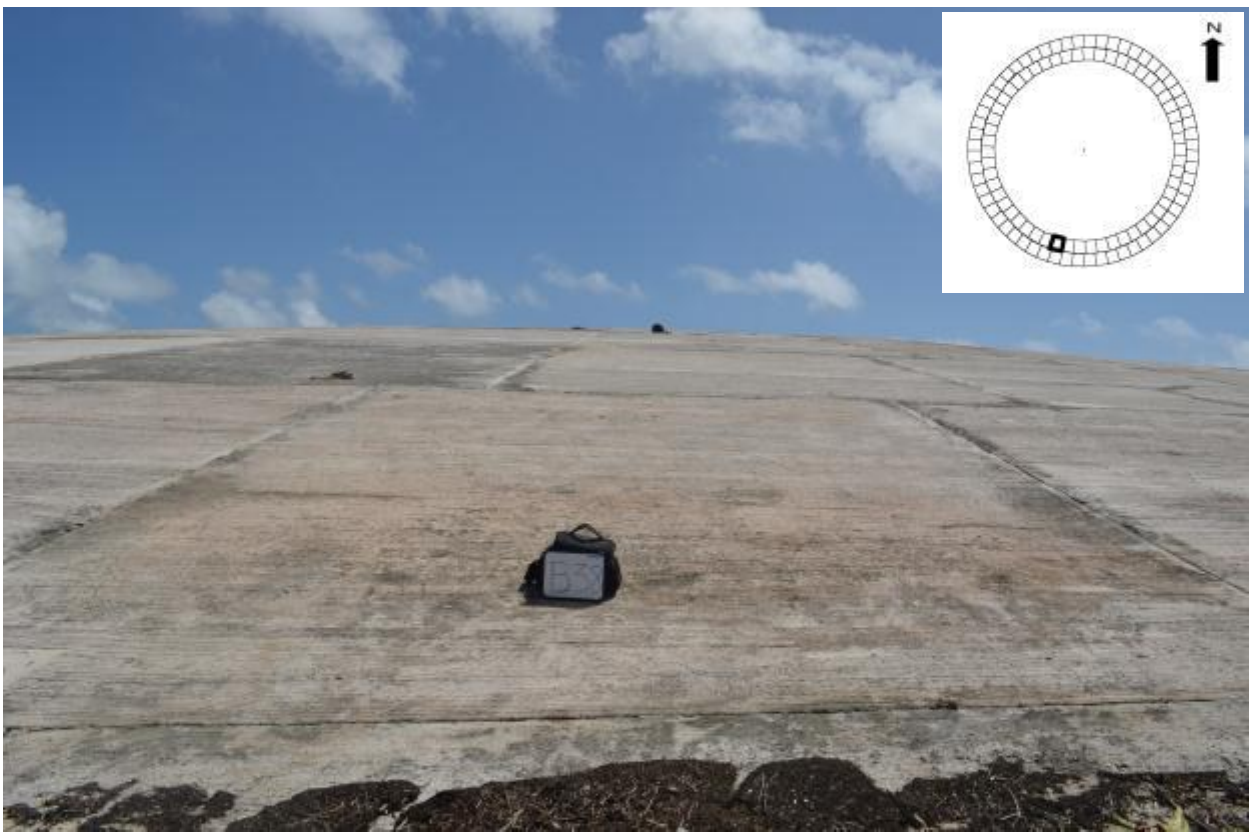
No significant or obvious interior cracks extending across the top of the panel. The panel appears to have a relatively rough appearance. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B38

Description

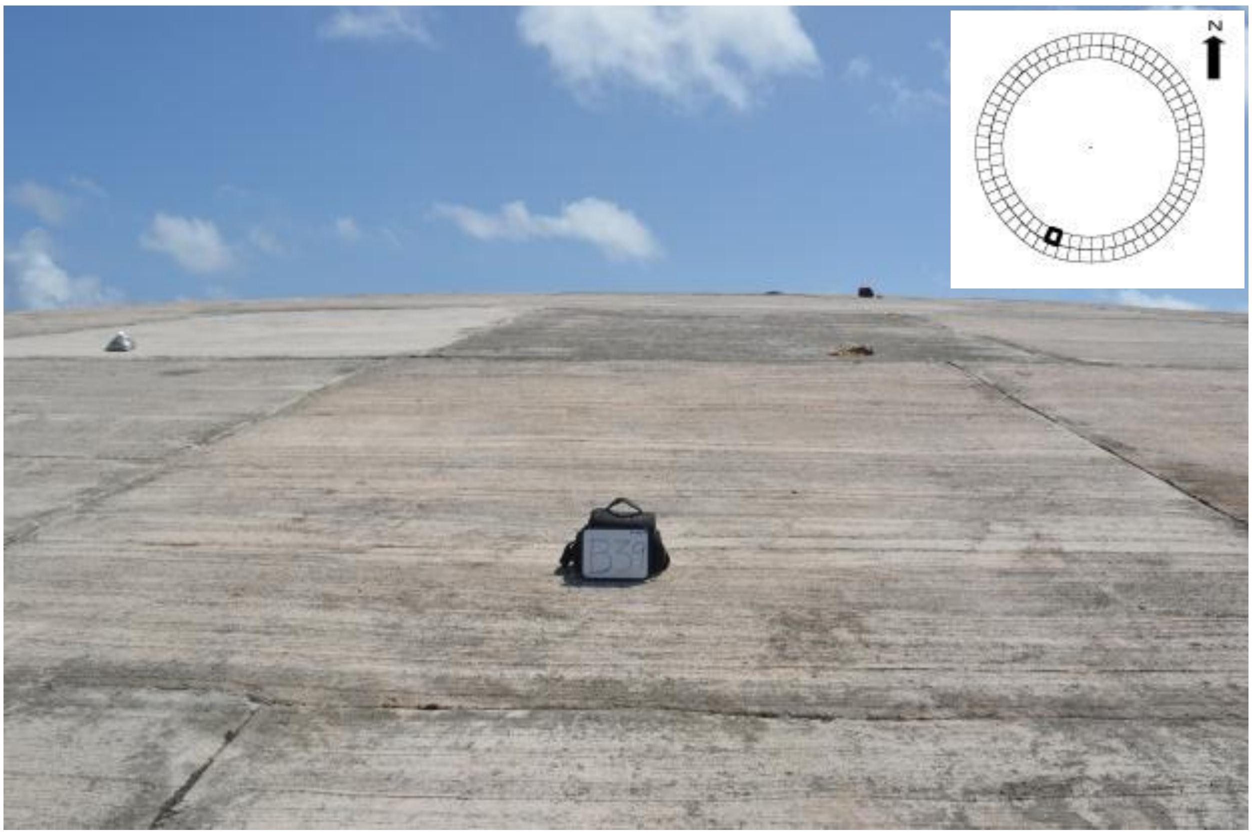
No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed in the bottom left-hand corner of the panel. There appears to be deeper and more obvious cracks running along the seam joints compared with those appearing around the majority of panels.



CAP SECTION LOCATION: Panel B39

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough appearance. Some minor spalling of concrete observed in the lower left and right-hand corners of the panel, and along the right-hand side of the upper seam.



CAP SECTION LOCATION: Panel B40

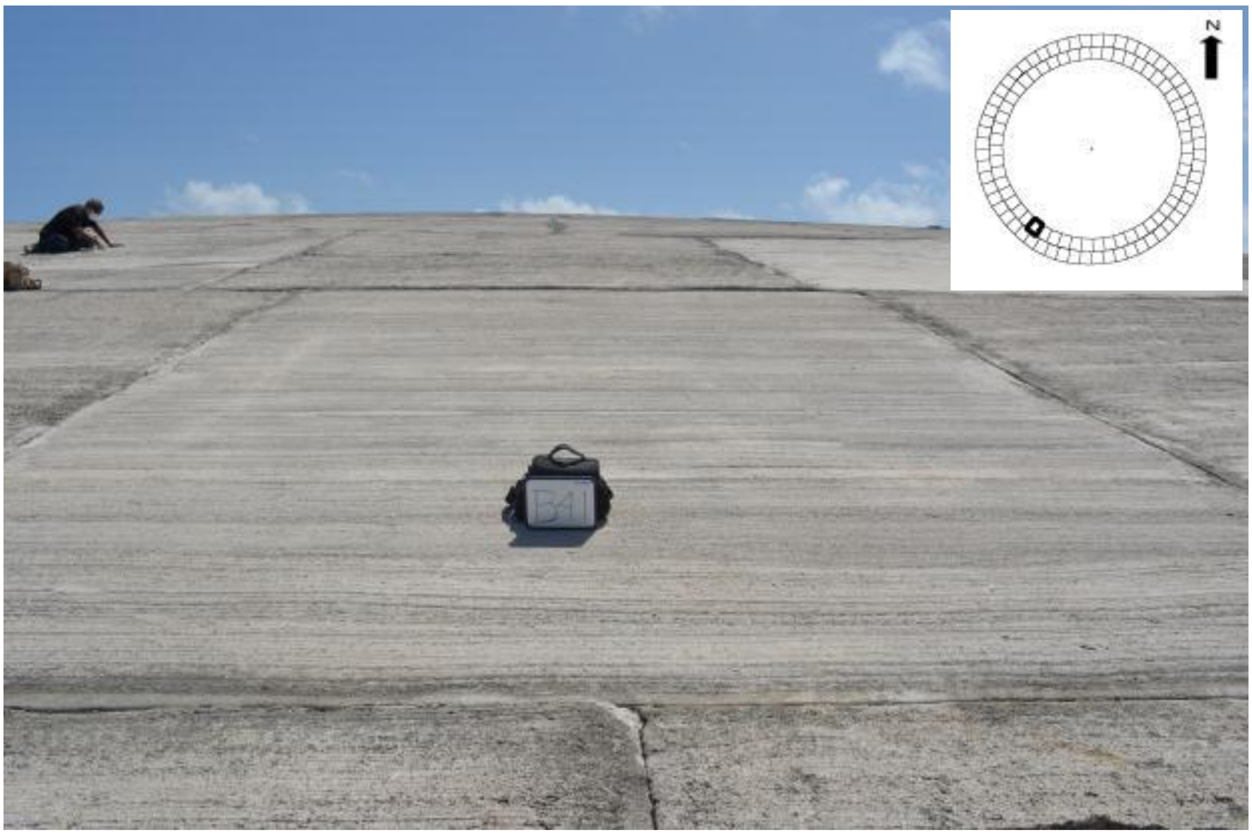
Description

There is a significantly cracked section of concrete with spalled edges in the lower left-hand corner of the panel. Some minor spalling of concrete also observed in the upper left-hand corner of the panel.

CAP SECTION LOCATION: Panel B41

Description

No significant or obvious interior cracks extending across the top of the panel. Some spalling/cracking of concrete observed along the right side of the bottom seam, and in the lower left-hand corner, of the panel.



CAP SECTION LOCATION: Panel B42

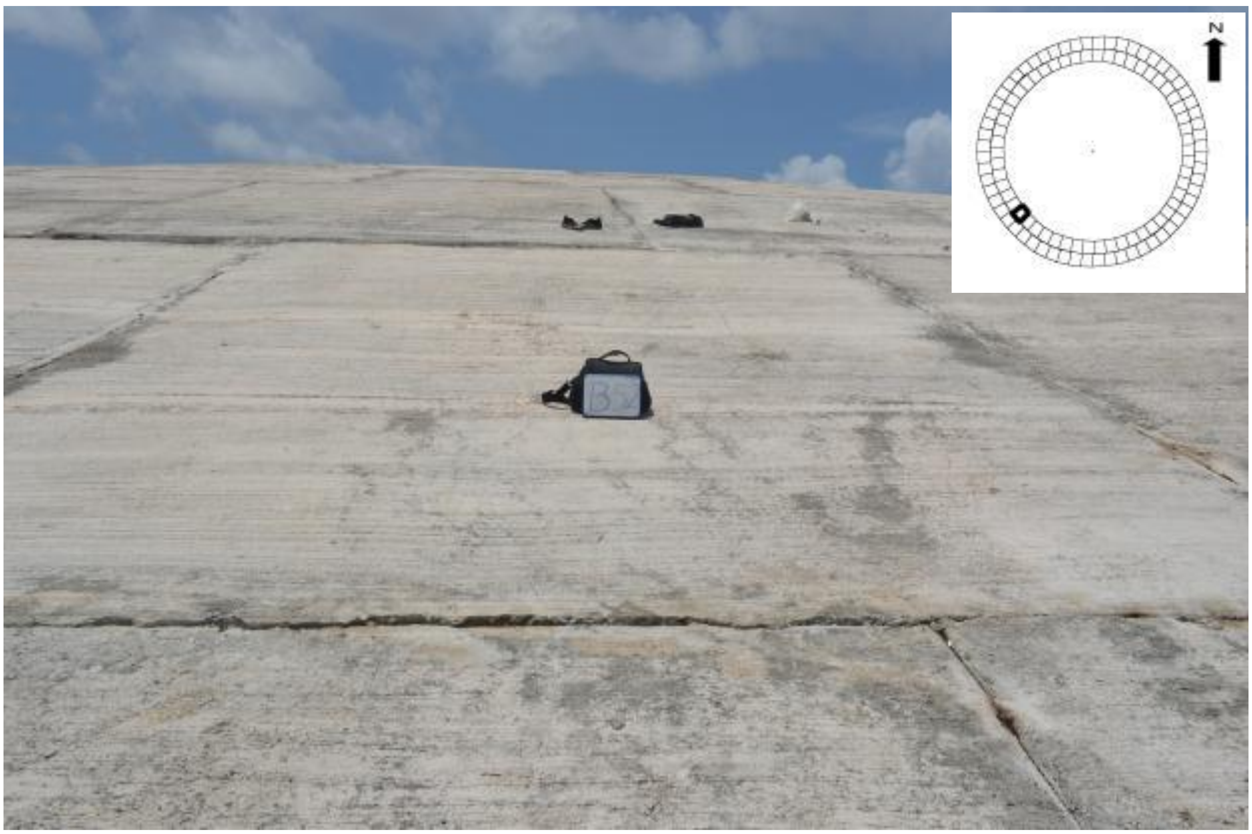
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. There is a significantly cracked/spalled section of concrete in the lower right-hand corner of the panel. Rooting vegetation removed from along the panel seams. Panel B43 to B51 were skipped.

CAP SECTION LOCATION: Panel B52

Description

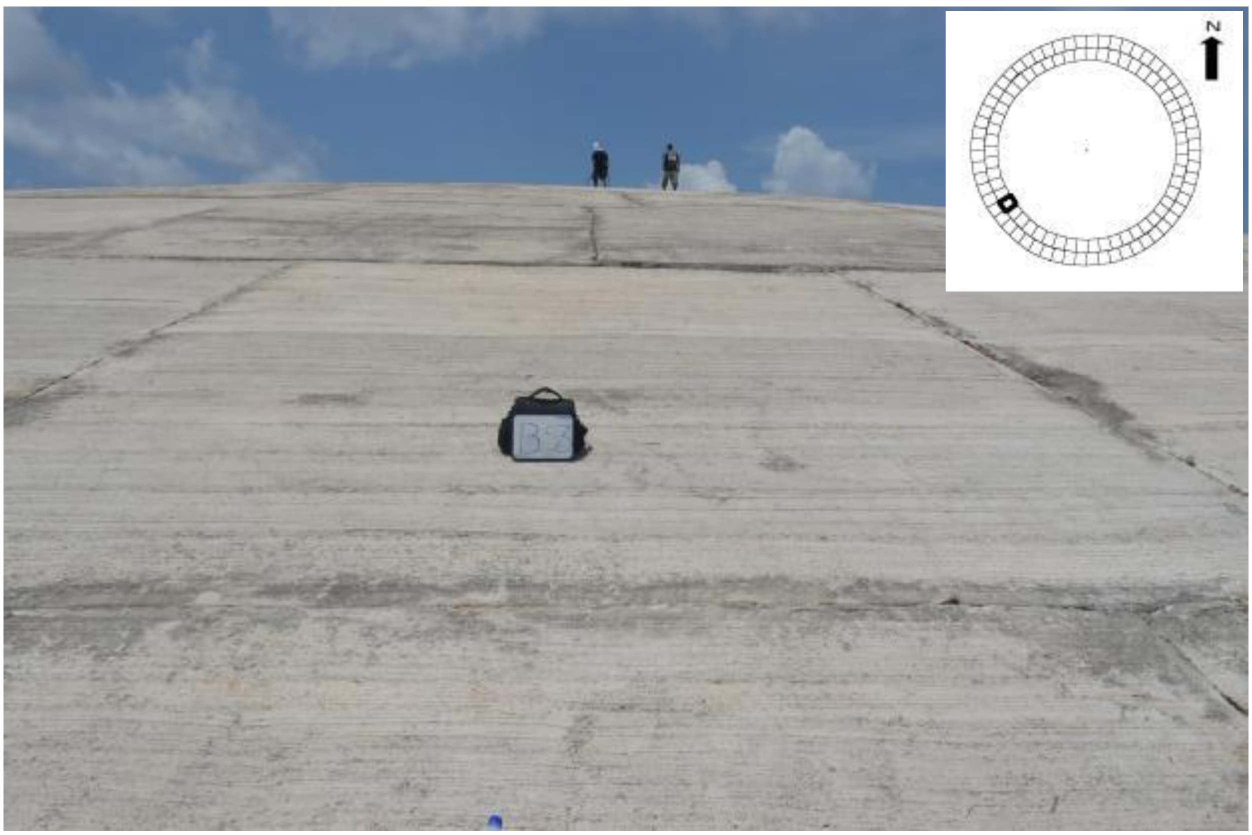
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. There is some minor spalling of concrete in the lower right-hand corner of the panel, and along the bottom seam overhanging the A panel below.



CAP SECTION LOCATION: Panel B53

Description

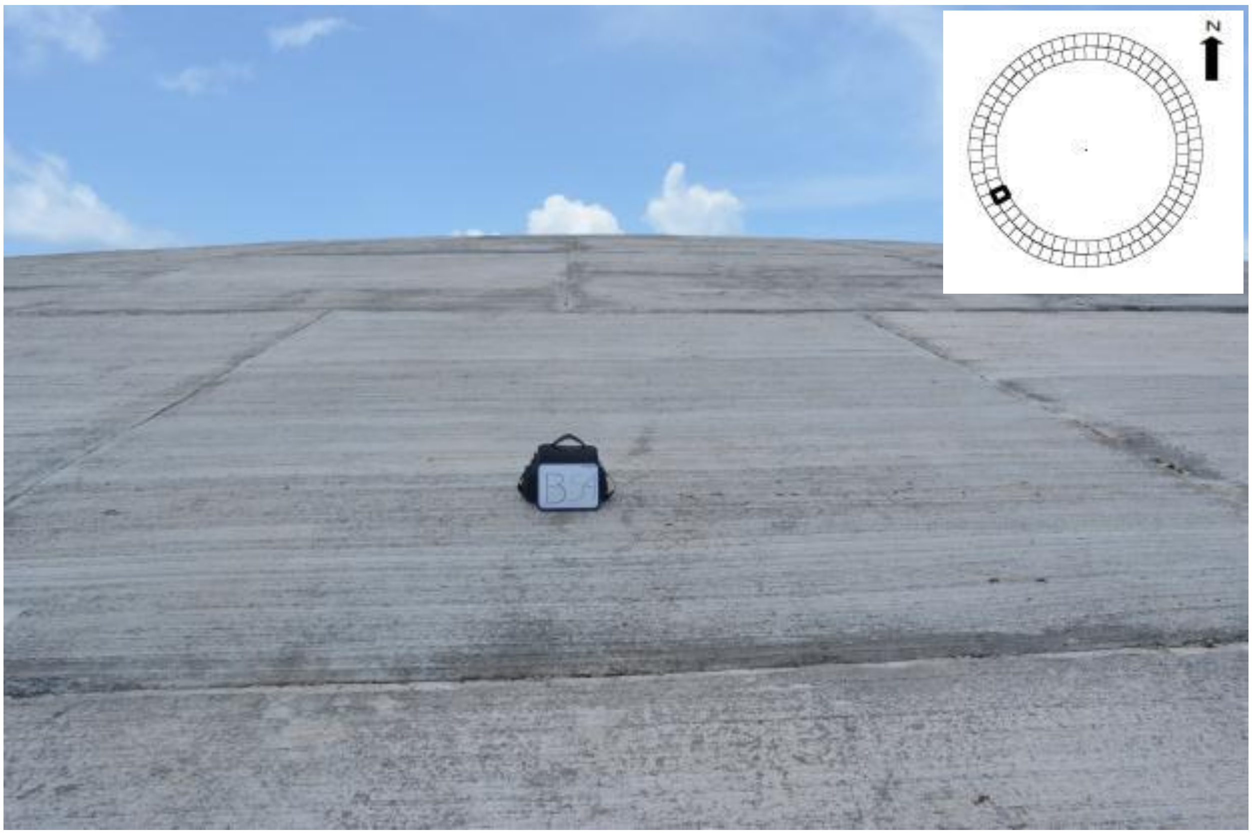
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some spalling of concrete observed in the lower right-hand corner of the panel.



CAP SECTION LOCATION: Panel B54

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed along the bottom seam on the left side of the panel, and at the intersecting corner with the A panel on right side of the panel.



CAP SECTION LOCATION: Panel B55

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed along the bottom edge of the panel overhanging the A rig row.

CAP SECTION LOCATION: Panel B56

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Cracking/spalling of concrete observed along the upper right-hand seam. Rooting vegetation (grass and vines) removed from along the panel seams.

CAP SECTION LOCATION: Panel B57

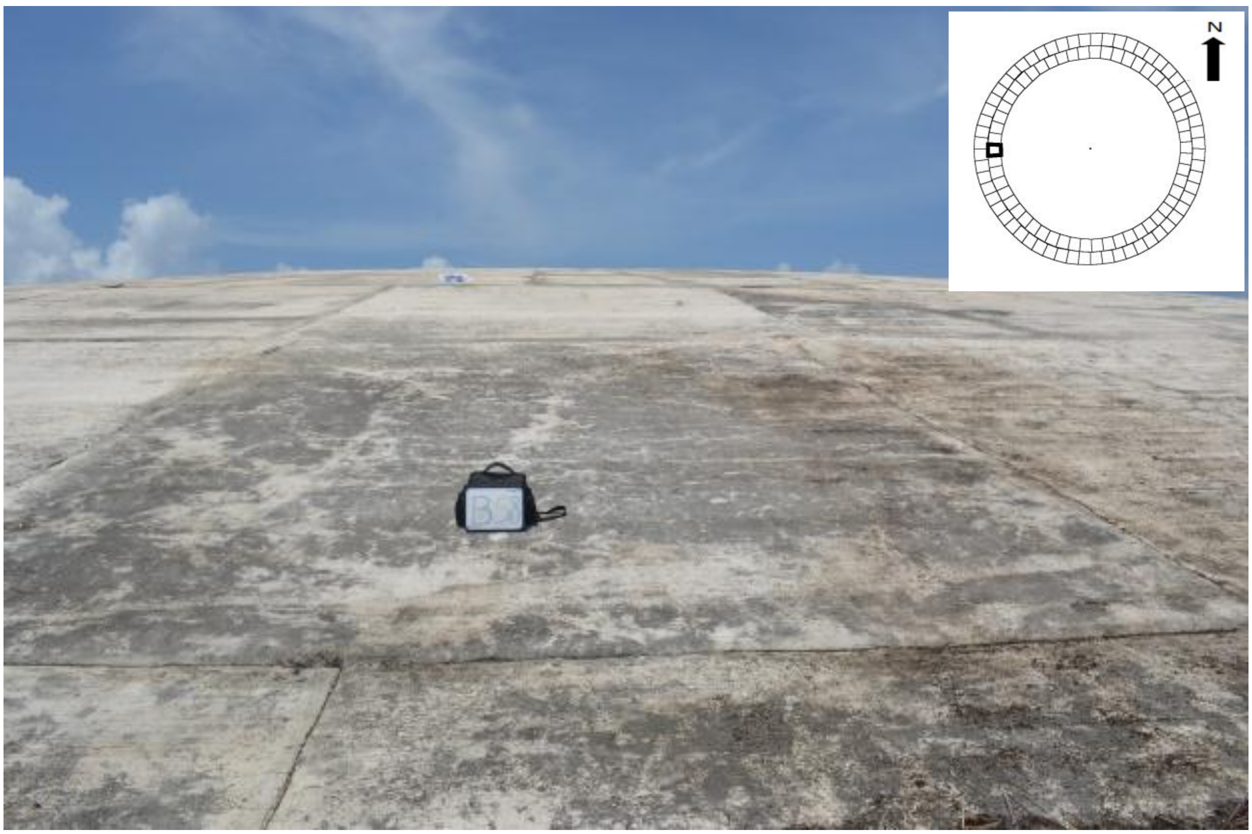
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel B58

Description

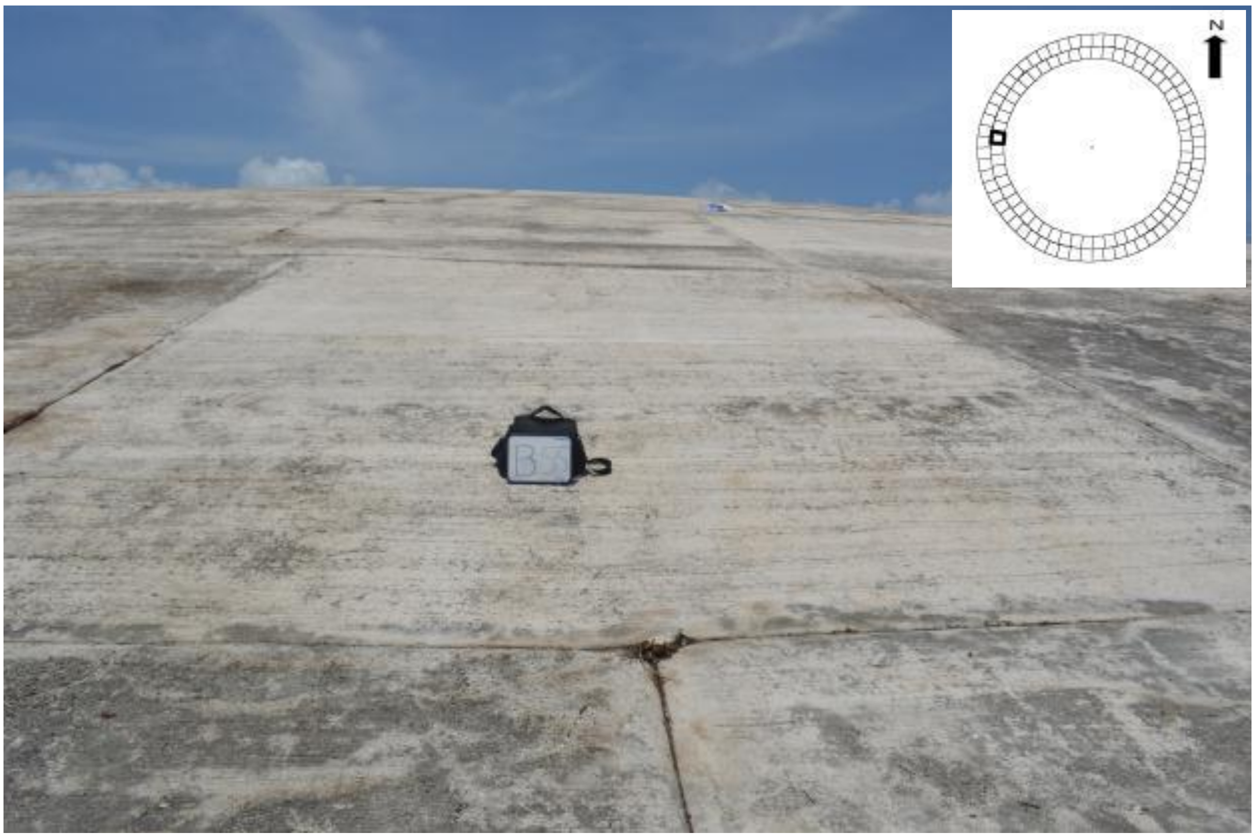
No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. There is some minor spalling of concrete in the upper left and right-hand corners of the panel, and along the bottom seam adjacent to intersecting corner of the A panels below.



CAP SECTION LOCATION: Panel B55_duplicate

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel B56_duplicate

Description

The panel has a relatively rough and weathered appearance.. Rooting vegetation removed from along the panel seams. A minor crack observed traversing across the segment at about a mid-point up the panel.

CAP SECTION LOCATION: Panel B57_duplicate

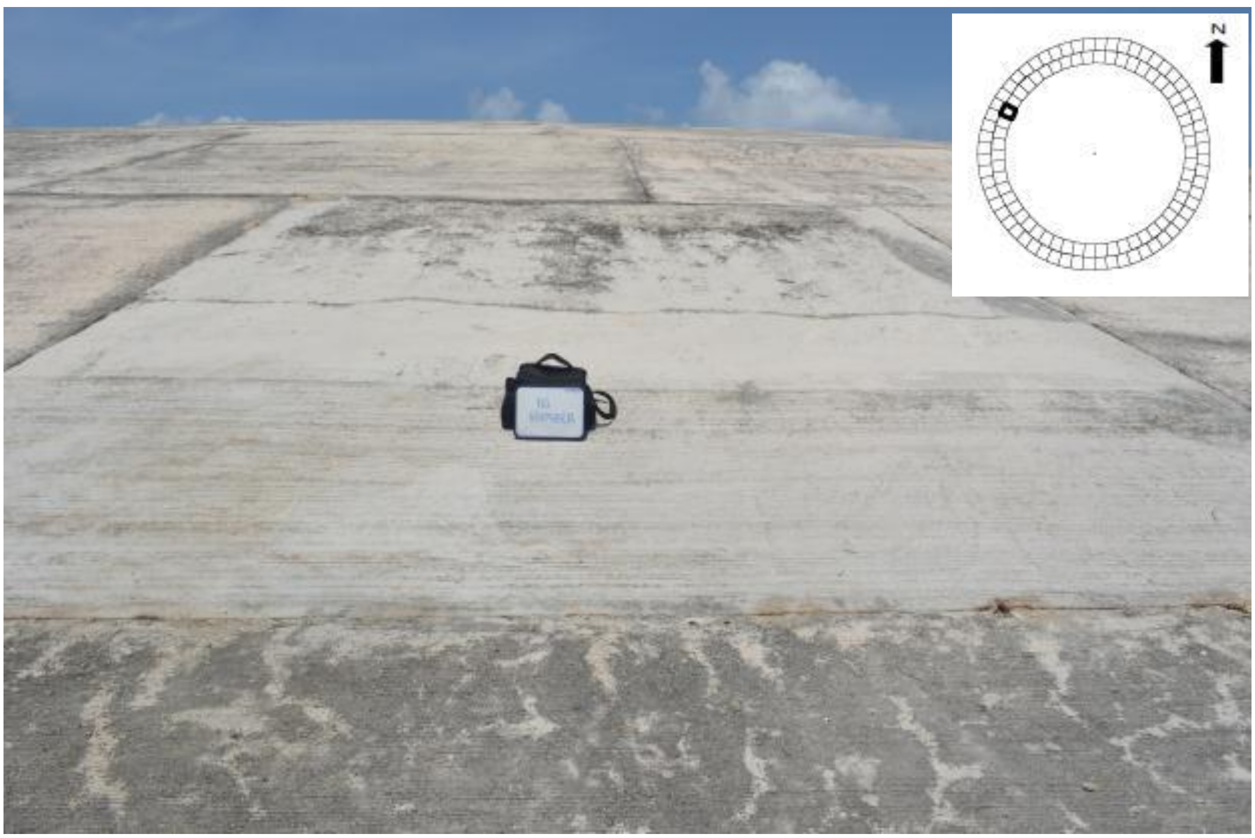
Description

Rooting vegetation removed from along the panel seams. A crack observed traversing across the segment between 2 to 3 meters up from the bottom of the panel.

CAP SECTION LOCATION: Panel No ID

Description

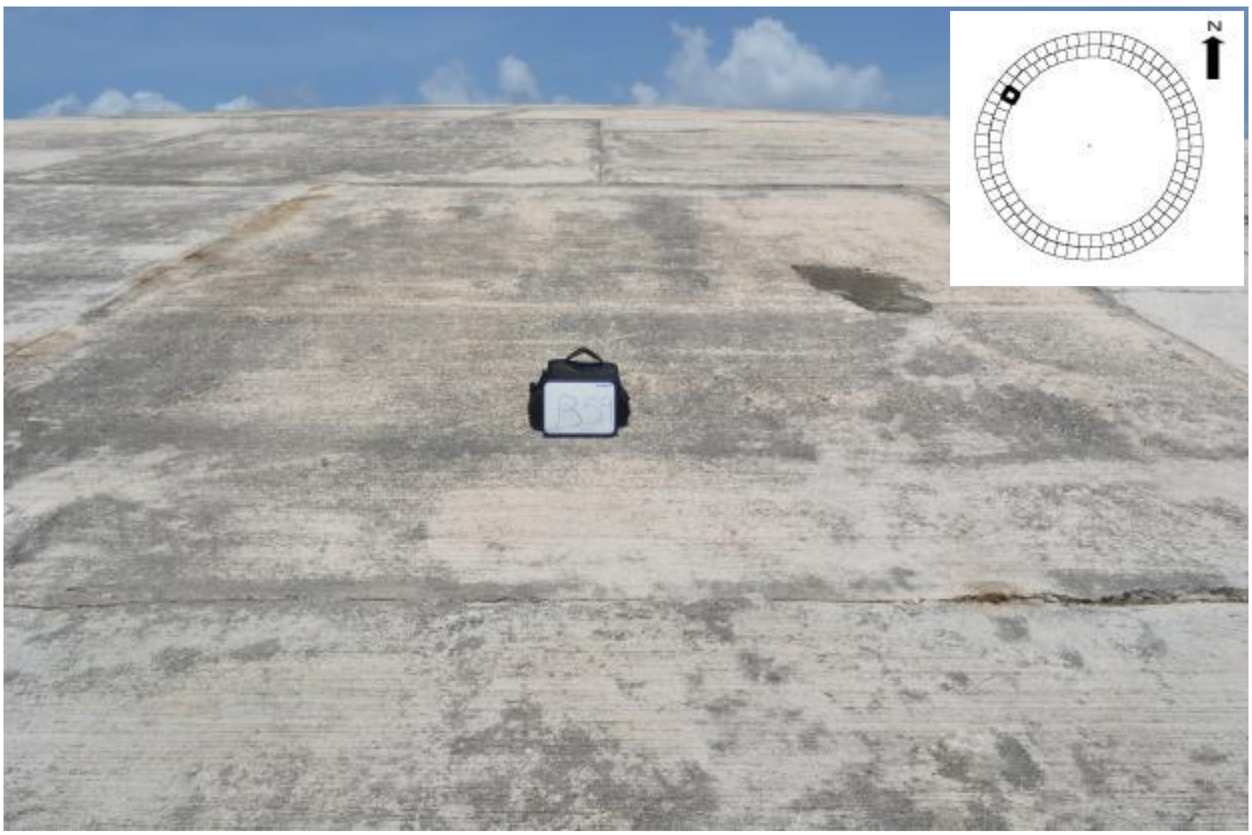
Rooting vegetation removed from along the panel seams. A crack observed traversing across the segment at about a mid-point up the panel. Some spalling of concrete observed in the bottom right-hand corner of the panel as well as along the bottom seam at the intersecting corner with the A panels below.



CAP SECTION LOCATION: Panel B59

Description

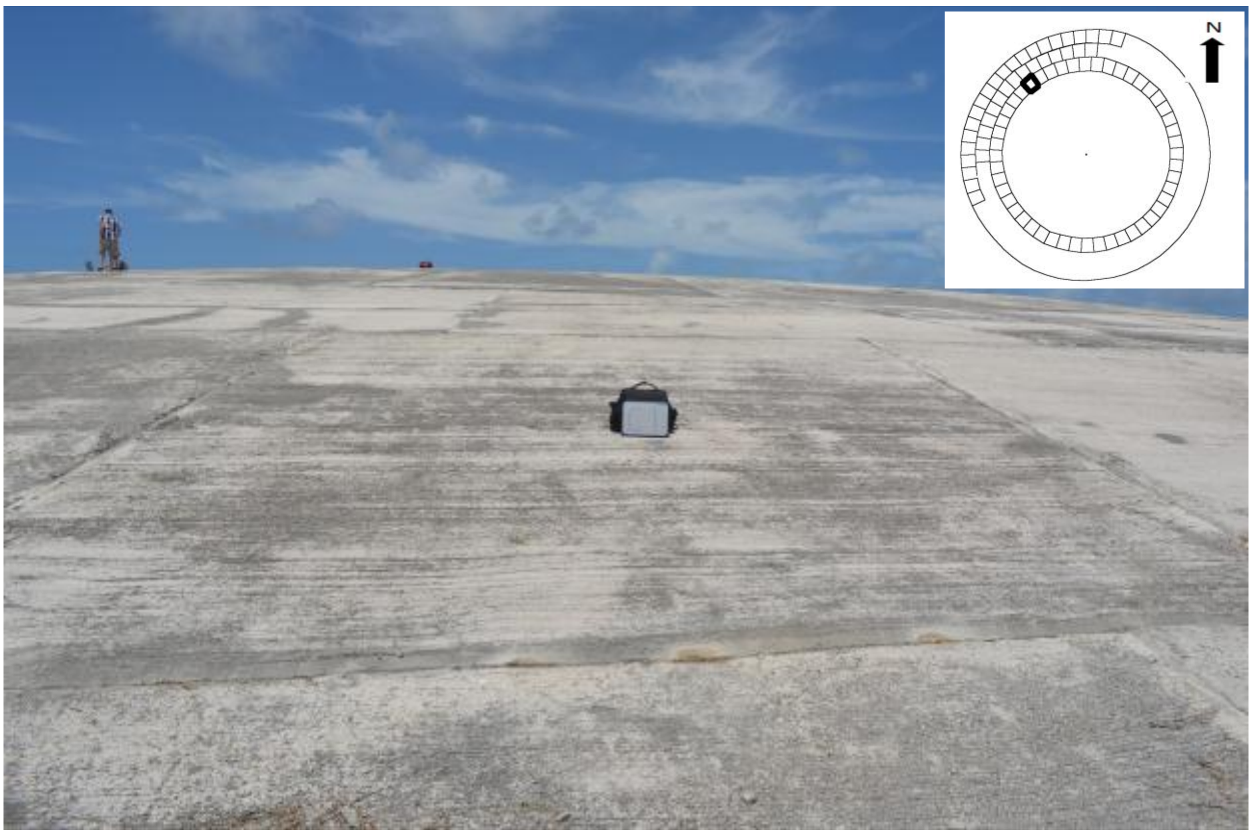
No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams. Some spalling of concrete observed along the lower left and right-hand seams, and along the bottom seam at the intersecting corner with the A panels below. There is some indication of a secondary patch of concrete overlaying the panel at about a mid-point up the panel on the right side (refer to photo).



CAP SECTION LOCATION: Panel C1

Description

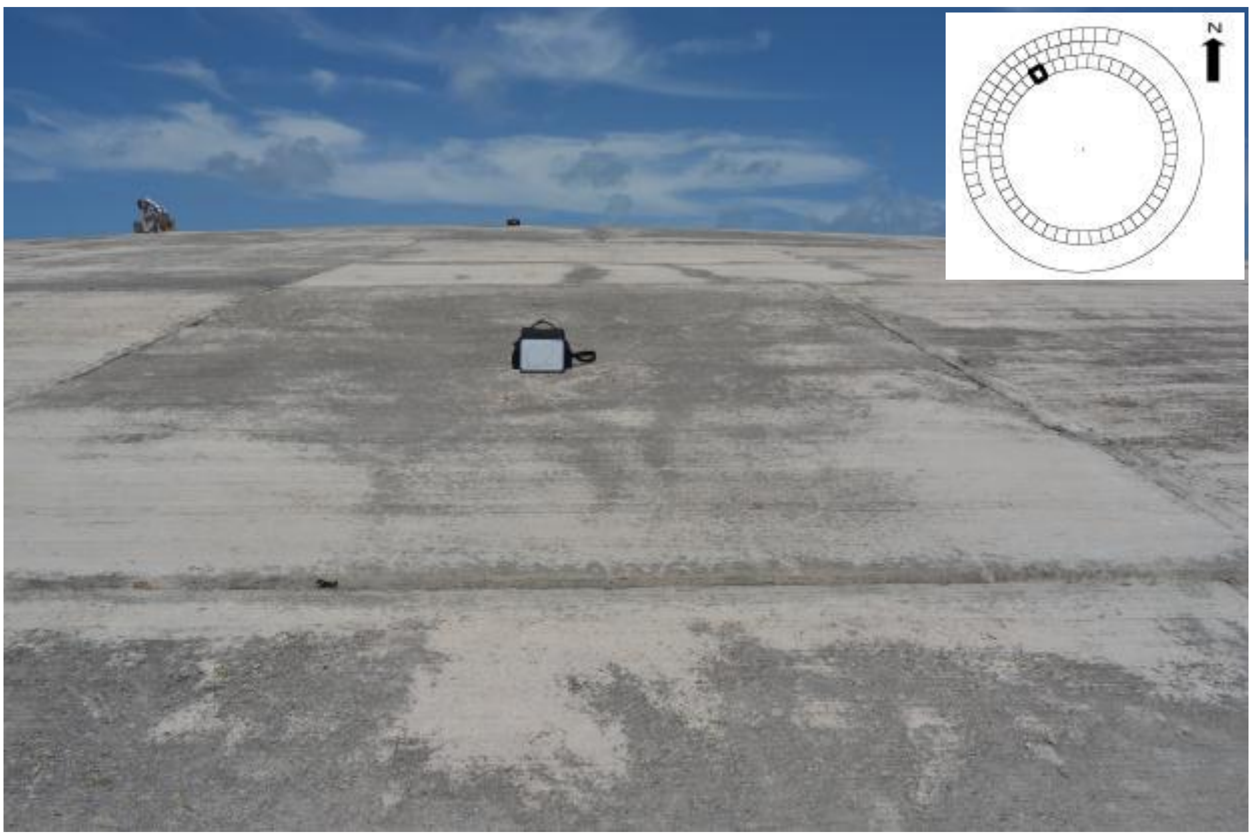
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed along the upper seam overlapping the D panel above.



CAP SECTION LOCATION: Panel C2

Description

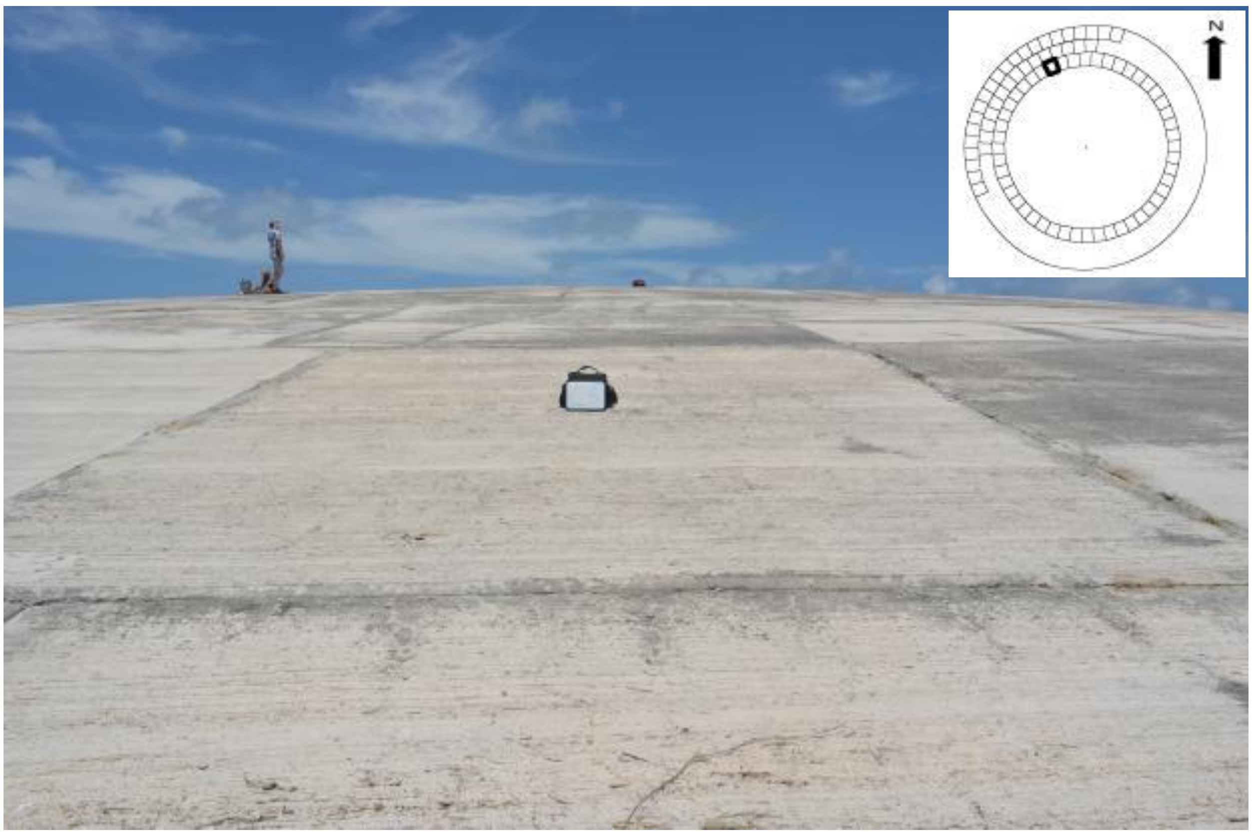
No significant or obvious interior cracks extending across the top of the panel. The panel has a slightly more rough and weathered appearance. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel C3

Description

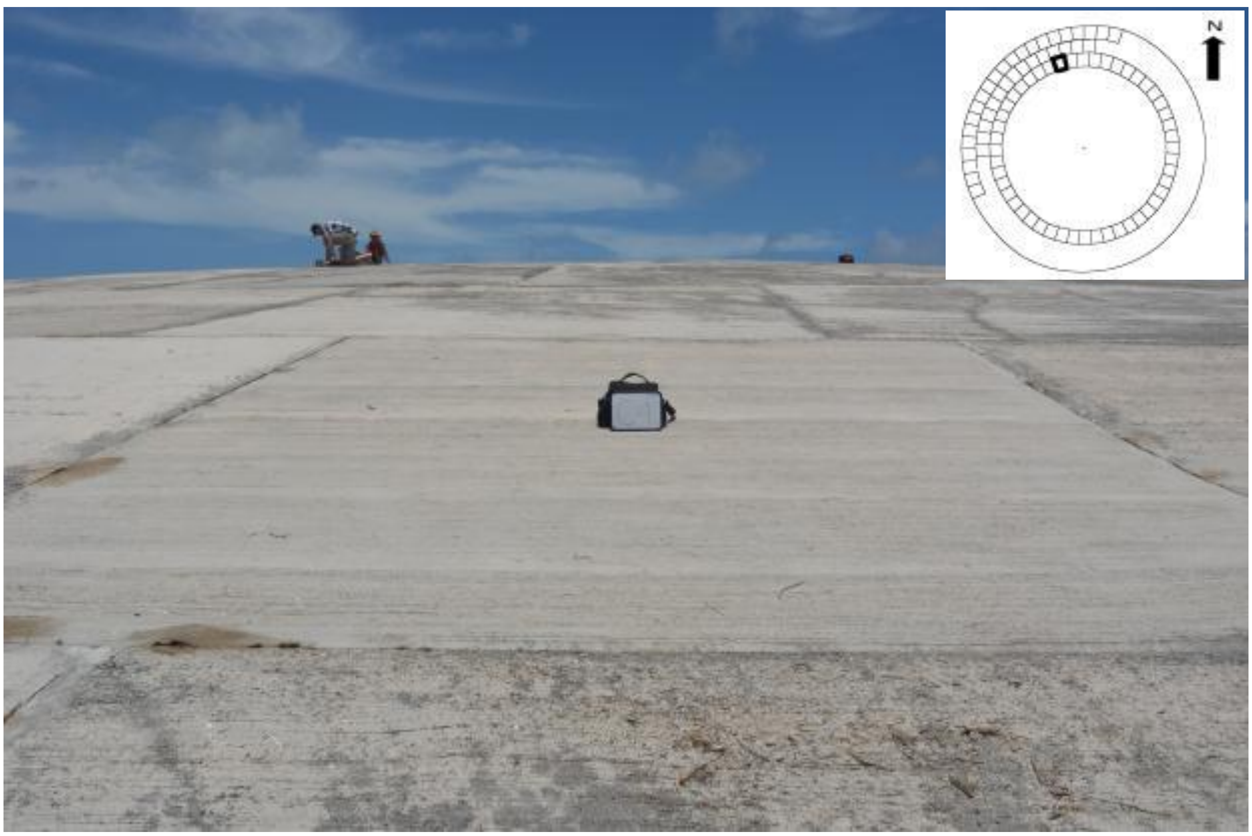
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel C4

Description

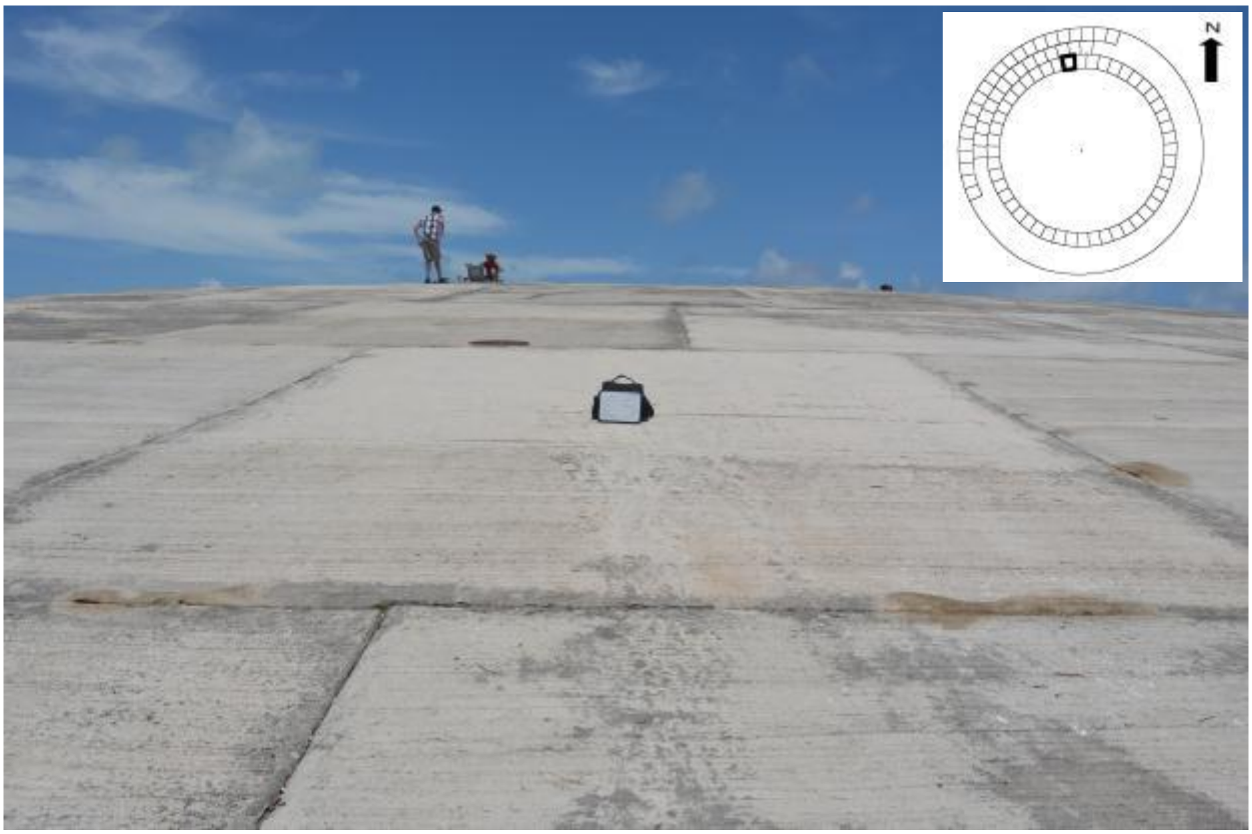
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel C5

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed in the upper left-hand corner and along the upper seam overlapping the D panels above.



CAP SECTION LOCATION: Panel C6

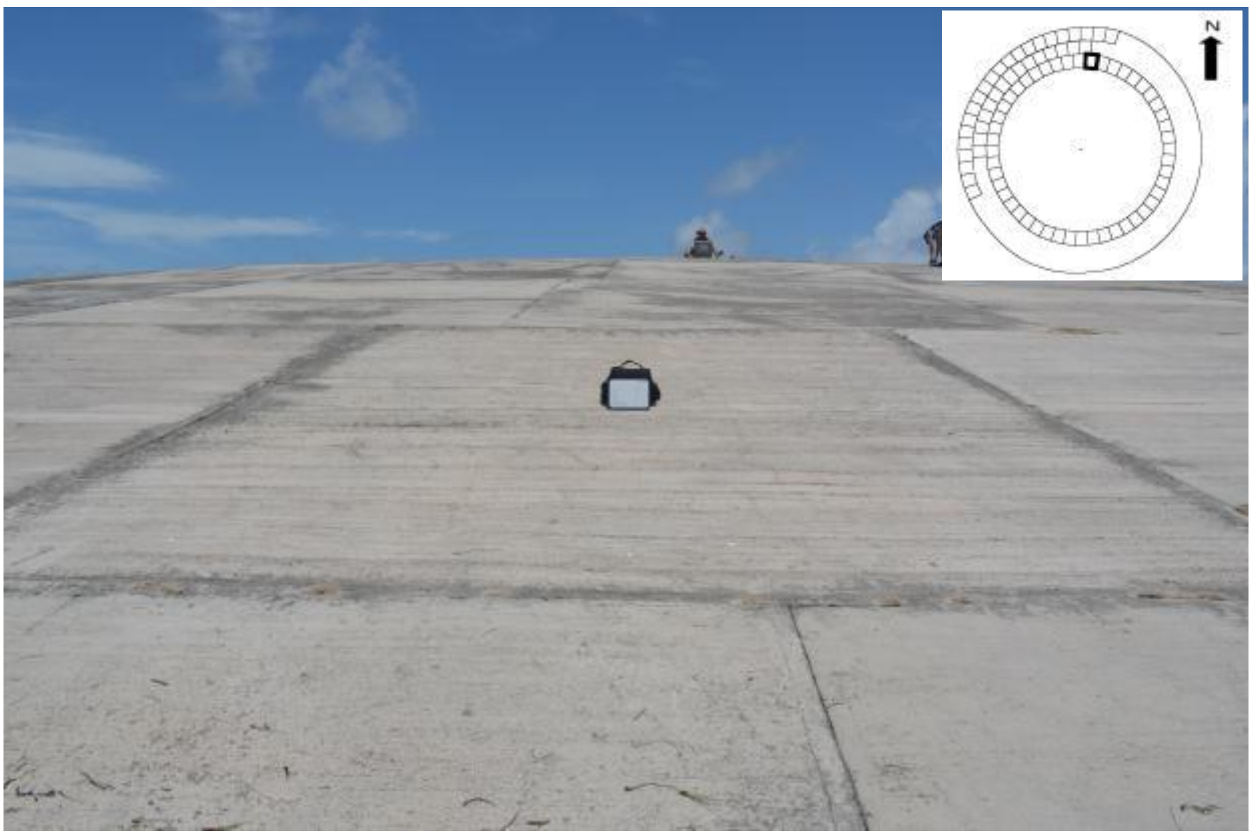
Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel C7

Description

No significant or obvious interior cracks extending across the top of the panel. Panel appears rough and weathered. Rooting vegetation removed from along the panel seams. Some minor spalling of concrete observed in the upper left-hand corner of the panel.



CAP SECTION LOCATION: Panel C8

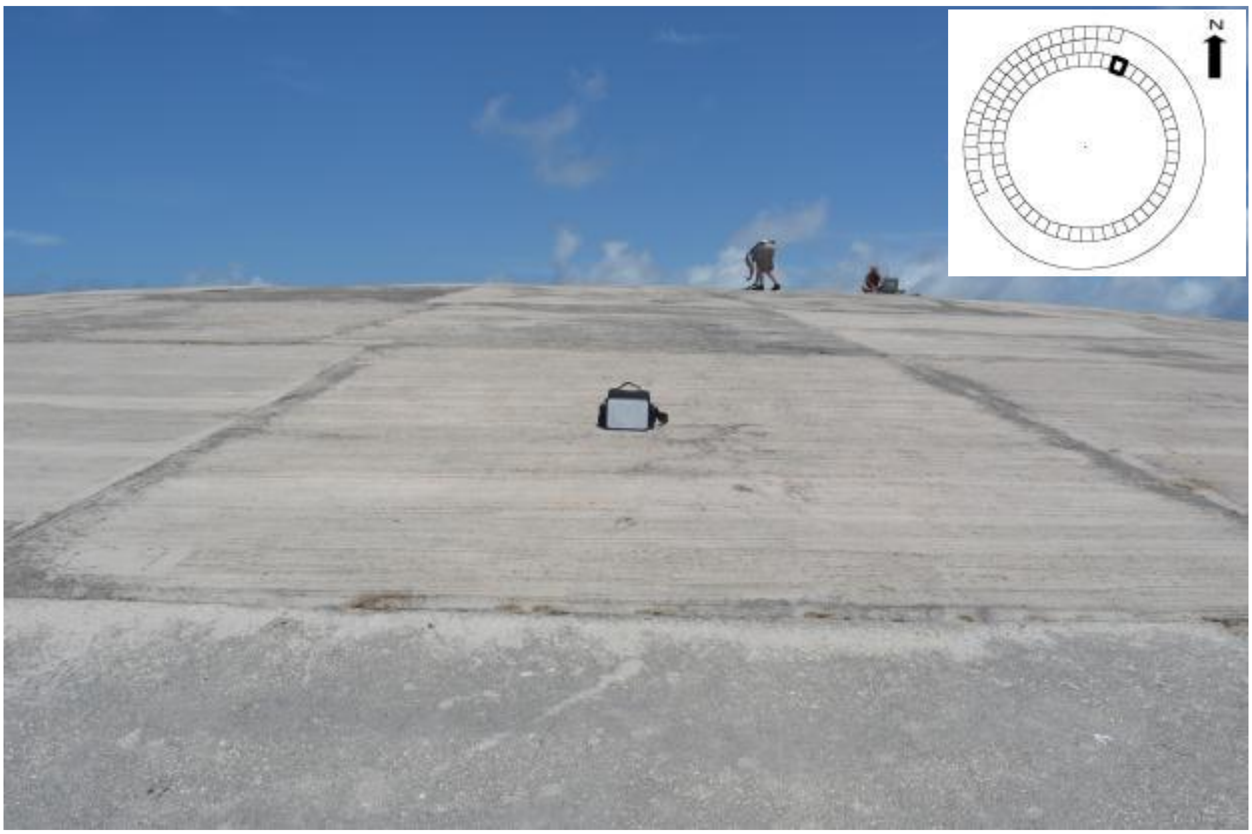
Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel C9

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel C10

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel C11

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel C12

Description

No significant or obvious interior cracks extending across the top of the panel. Some minor spalling/chipping of concrete observed in the lower left-hand corner of the panel.

CAP SECTION LOCATION: Panel C13

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance.

CAP SECTION LOCATION: Panel C14

Description

No significant or obvious interior cracks extending across the top of the panel with exception of a small void found in the concrete app. 2 centimeters deep and about 2 x 1.5 centimeters in area. Rooting vegetation removed from along the panel seams. This panel contains a filled drill-hole (CD-12) from the 1980 NAS investigation.

CAP SECTION LOCATION: Panel C15

Description

No significant or obvious interior cracks extending across the top of the panel. Some minor spalling/chipping of concrete observed in the lower and top left-hand corners of the panel.

CAP SECTION LOCATION: Panel C16

Description

Some spalling/chipping of concrete observed in the bottom left-hand and right-hand corners of the panel as well as along the bottom portion of the left seam and along the bottom seam adjacent to intersecting corners between panel B19 and B20. Spalling of concrete was also evident along the central portion of the top seam. A surface crack was observed traversing across the segment at a mid-point up the panel.

CAP SECTION LOCATION: Panel C17

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some minor spalling/chipping of concrete observed in the lower right-hand corner of the panel.

CAP SECTION LOCATION: Panel C18

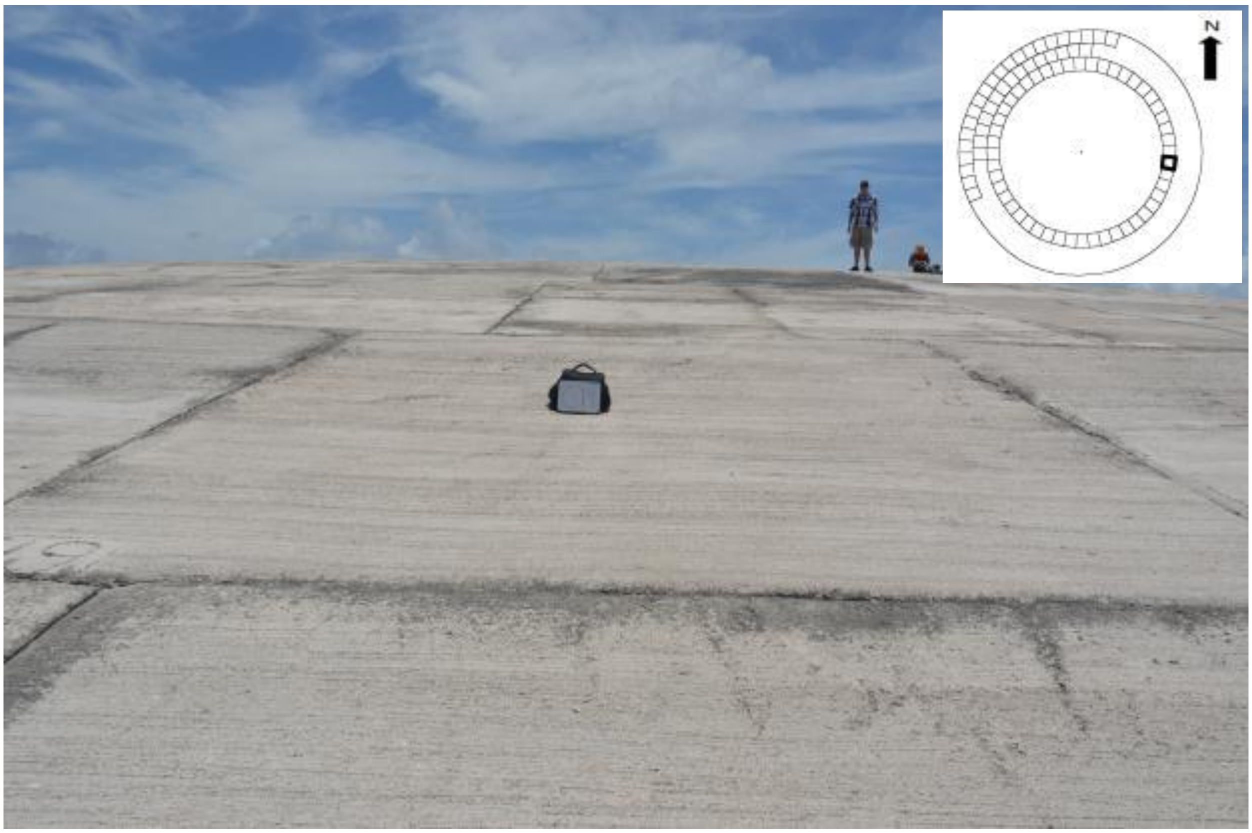
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance, especially in the upper portion of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel C19

Description

No significant or obvious interior cracks extending across the top of the panel. Some minor spalling/chipping of concrete observed in the lower right-hand corner of the panel. The right-hand side of the panel appears to be slightly undulated – perhaps due to panel settlement. This is supported by the observation that there appears to be more separation (i.e., a larger gap) along the seams compared with any adjacent panels.



CAP SECTION LOCATION: Panel C20

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough weathered appearance, especially across the upper portion of the panel. Some minor spalling/chipping of concrete observed in the upper right-hand corner, and along the bottom seam of the panel – especially around the intersecting corner with panel B24/B25 on the ring row below.

CAP SECTION LOCATION: Panel C21

Description

No significant or obvious interior cracks extending across the top of the panel. Minor spalling/cracking of concrete observed in the upper left-hand corner and along the right side of the bottom seam.

CAP SECTION LOCATION: Panel C22

Description

Upper sections of the panel have a slightly more rough and weathered appearance. Minor interior cracks extending across the top of the panel. Some spalling/cracking of concrete observed along the left side of the bottom seam.

CAP SECTION LOCATION: Panel C23

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a slightly more rough and weathered appearance. The cracks along the seam lines appear to be deeper and more obvious.

CAP SECTION LOCATION: Panel C22_duplicate (position C24)

Description

The panel occupies position C24. Cracks along the seam lines appear to be deeper and more obvious. Spalling of concrete in the lower right-hand corner – the affected section of concrete occupies an area approaching 1 m^2. A small void about 2 centimeters deep and 2 x 1-1.5 centimeters in area was also observed on the upper right-hand side of the panel.

CAP SECTION LOCATION: Panel C25

Description

No significant or obvious interior cracks extending across the top of the panel. The cracks along the panel joints appear to be deeper and more obvious compared with panels in adjacent ring rows. Some spalling/cracking of concrete observed in the lower right-hand corner of the panel.

CAP SECTION LOCATION: Panel C26

Description

No significant or obvious interior cracks extending across the top of the panel. Very minor spalling of concrete observed in the lower right-hand corner of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel C27

Description

No significant or obvious interior cracks extending across the top of the panel. Very minor spalling of concrete observed in the lower right corner. Some minor spalling of concrete is evident along the lip overhanging the upper left seam of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel C28

Description

No significant or obvious interior cracks extending across the top of the panel. The cracks along the seam lines appear to be deeper and more obvious compared with panels in adjacent ring rows. Very minor spalling of concrete observed in the lower right-hand corner of the panel. Some minor spalling of concrete observed along the bottom seam forming the intersecting corner between panel B33 and B34 below.

CAP SECTION LOCATION: Panel C29

Description

No significant or obvious interior cracks extending across the top of the panel. Some spalling of concrete is evident along the lip overhanging the lower and left seams of the panel. Minor spalling of concrete also observed along the right side of the upper seam.

CAP SECTION LOCATION: Panel C30

Description

No significant or obvious interior cracks extending across the top of the panel. The cracks along the panel joints appear to be deeper and more obvious compared with panels in adjacent ring rows.

CAP SECTION LOCATION: Panel C31

Description

Rooting vegetation removed from along the panel seams. Some spalling/cracking of concrete observed along the bottom seam adjacent the intersecting corner between panel B36 and B37. A surface crack extends out from the bottom of the panel and then forms a fork to the left and right edges at about a mid-point up the panel. Please note the crack line can easily be traced by observing the discoloration in the photo (refer to photo below).

CAP SECTION LOCATION: Panel C32

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some spalling/cracking of concrete observed in the bottom left-hand corner of the panel.

CAP SECTION LOCATION: Panel C33

Description

The panel has a rough and weathered appearance. The cracks along the panel joints appear to be deeper and more obvious compared with those appearing around panels on adjacent ring rows. A surface crack was observed extending across the segment at a mid-point up the panel.

CAP SECTION LOCATION: Panel C34

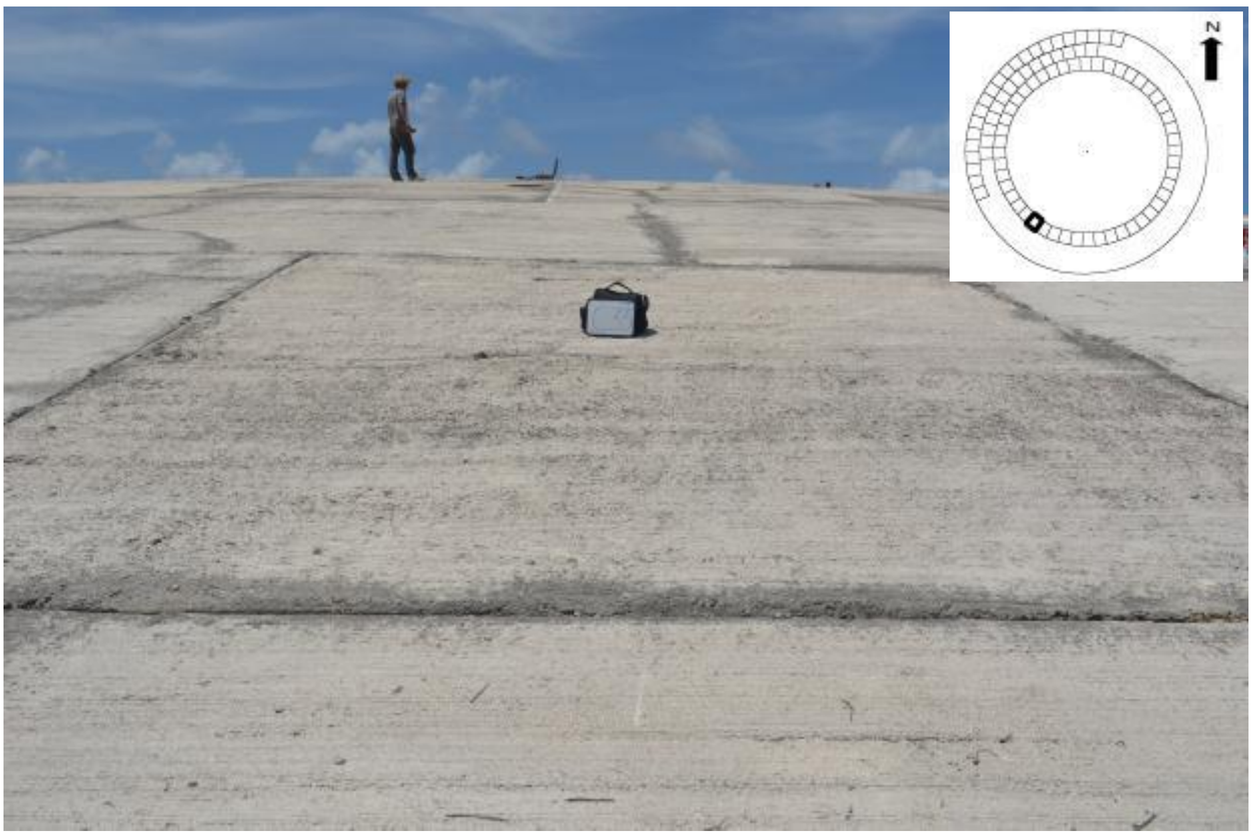
Description

No significant or obvious interior cracks extending across the top of the panel. The cracks along the panel joints appear to be deeper and more obvious compared with those appearing around panels on adjacent ring rows. Some spalling/cracking of concrete observed in the upper right-hand corner of the panel.

CAP SECTION LOCATION: Panel C35

Description

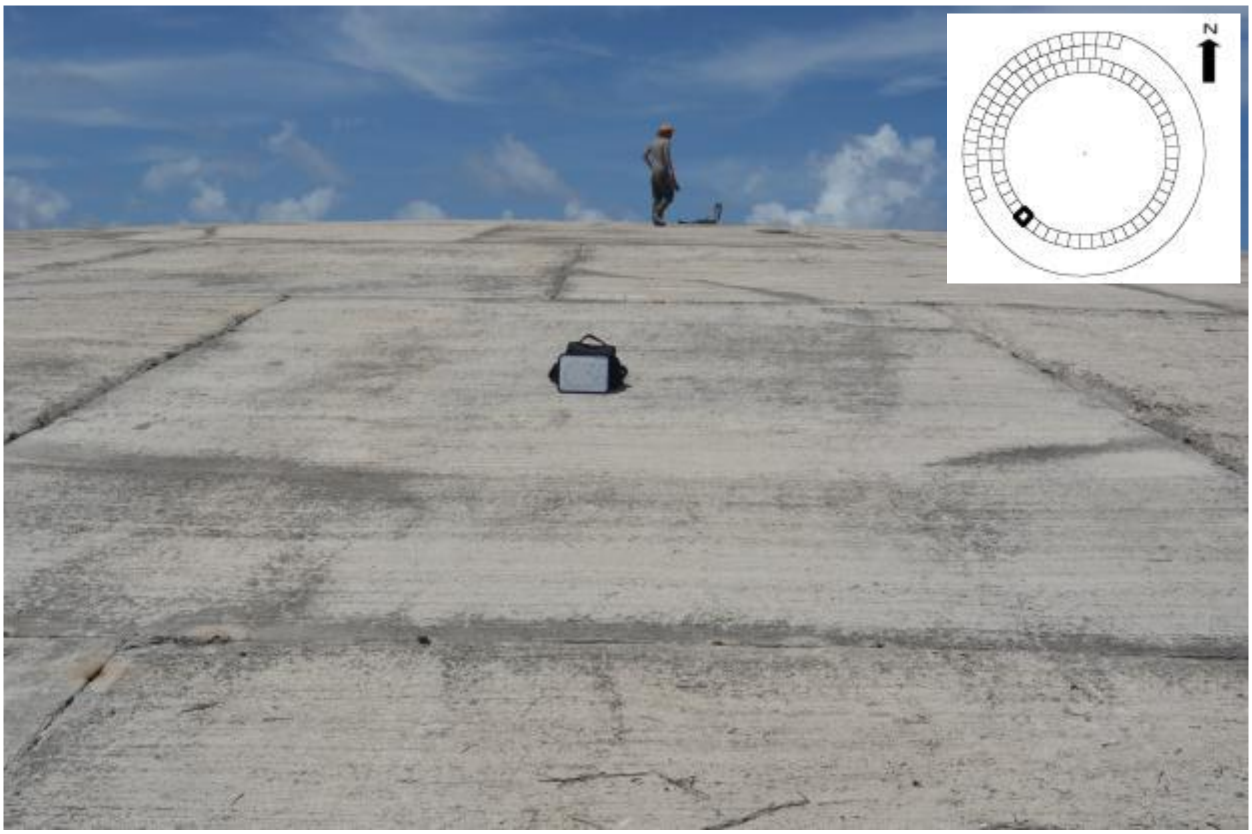
No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance. The cracks along the panel joints appear to be deeper and more obvious compared with those appearing around panels on adjacent ring rows. Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel C36

Description

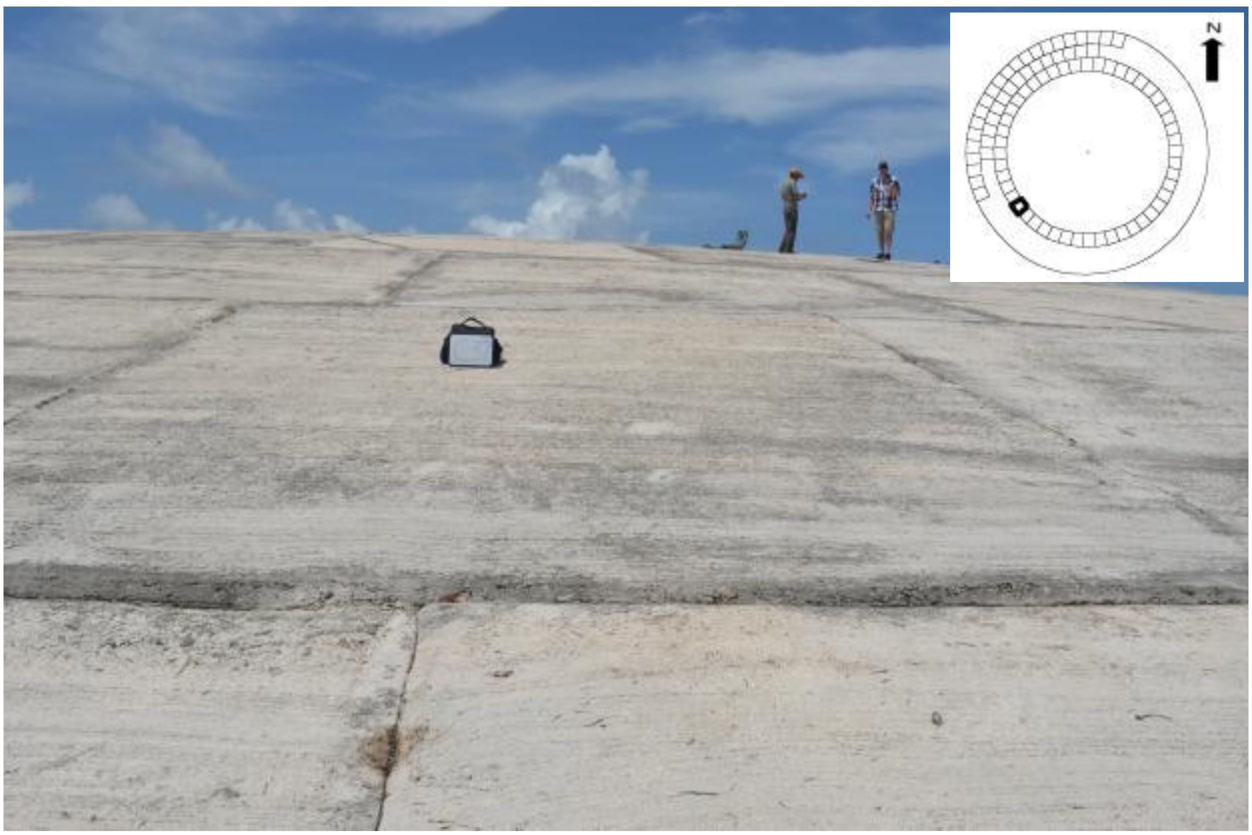
No significant or obvious interior cracks extending across the top of the panel. Some spalling/cracking of concrete observed in the upper right-hand corner of the panel. Rooting vegetation removed from along the panel seams. This panel contained a capped slotted PVC pipe bore-hole (CD-17) from the 1980 NAS investigation. The bore-hole was re-established during this visual survey for possible use as a groundwater sampling well.



CAP SECTION LOCATION: Panel C37

Description

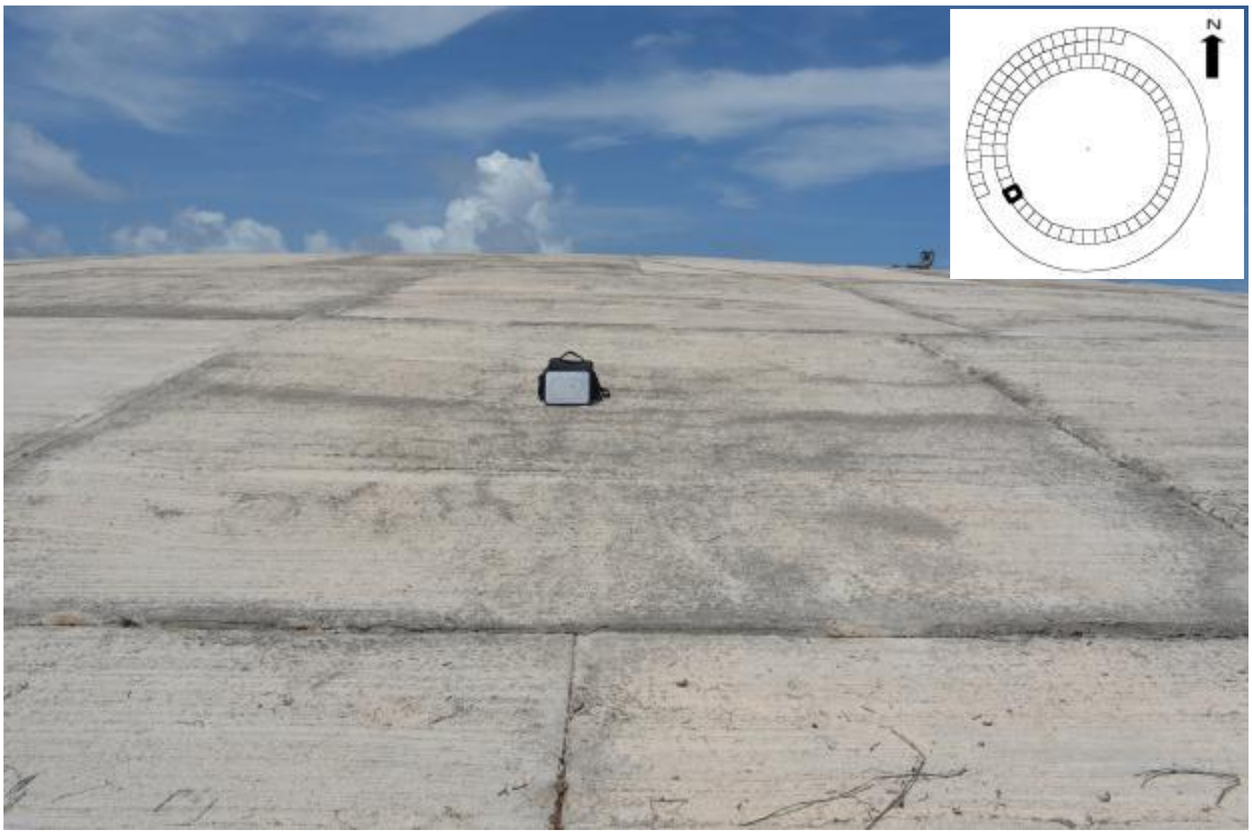
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. The cracks along the panel joints appear to be deeper and more obvious compared with those appearing around panels on adjacent ring rows. Some spalling/cracking of concrete observed in the bottom left-hand corner and along the left seam of the panel.



CAP SECTION LOCATION: Panel C38

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some spalling/cracking of concrete observed along the upper seam of the panel.



CAP SECTION LOCATION: Panel C39

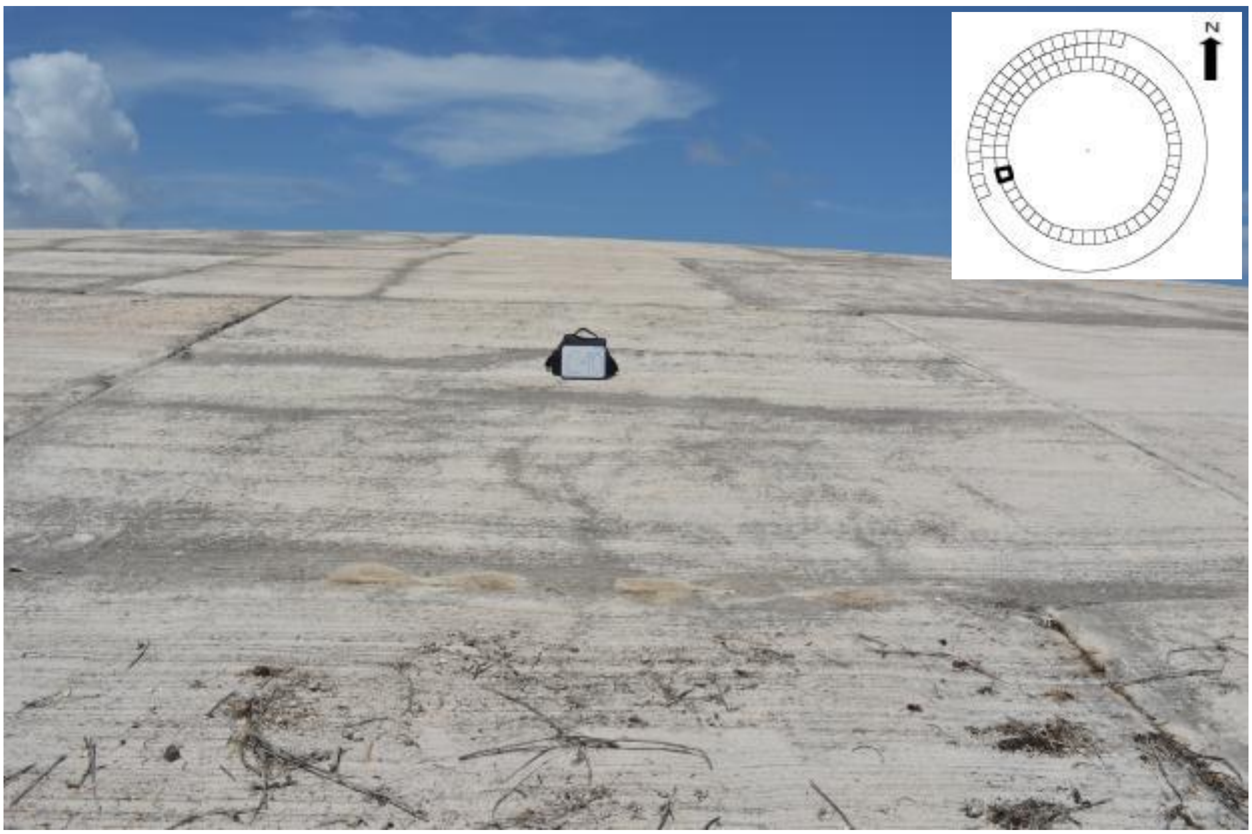
Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some spalling/cracking of concrete observed in the lower left-hand corner of the panel.

CAP SECTION LOCATION: Panel C40

Description

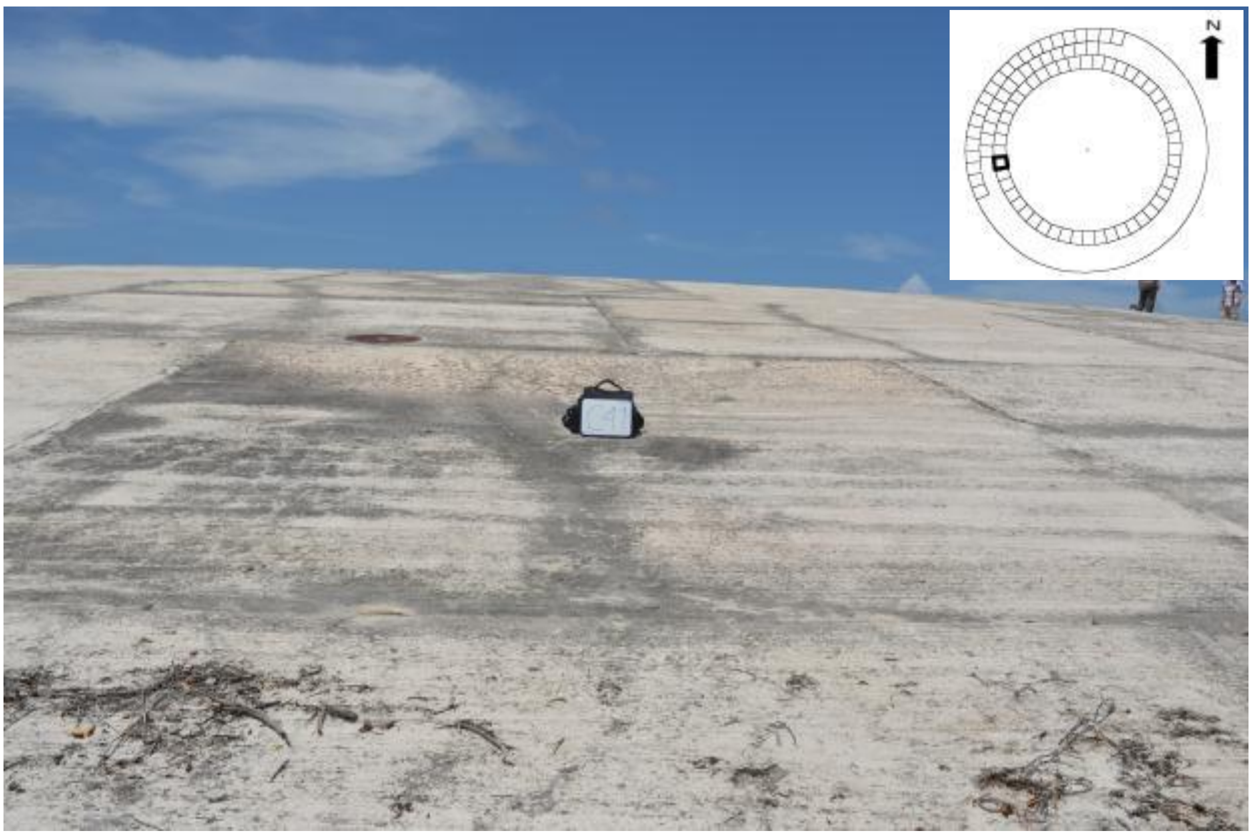
Rooting vegetation removed from along the panel seams. Some minor surface cracks traversing across the panel that appear to coincide with the dark shaded areas shown in the photo below.



CAP SECTION LOCATION: Panel C41

Description

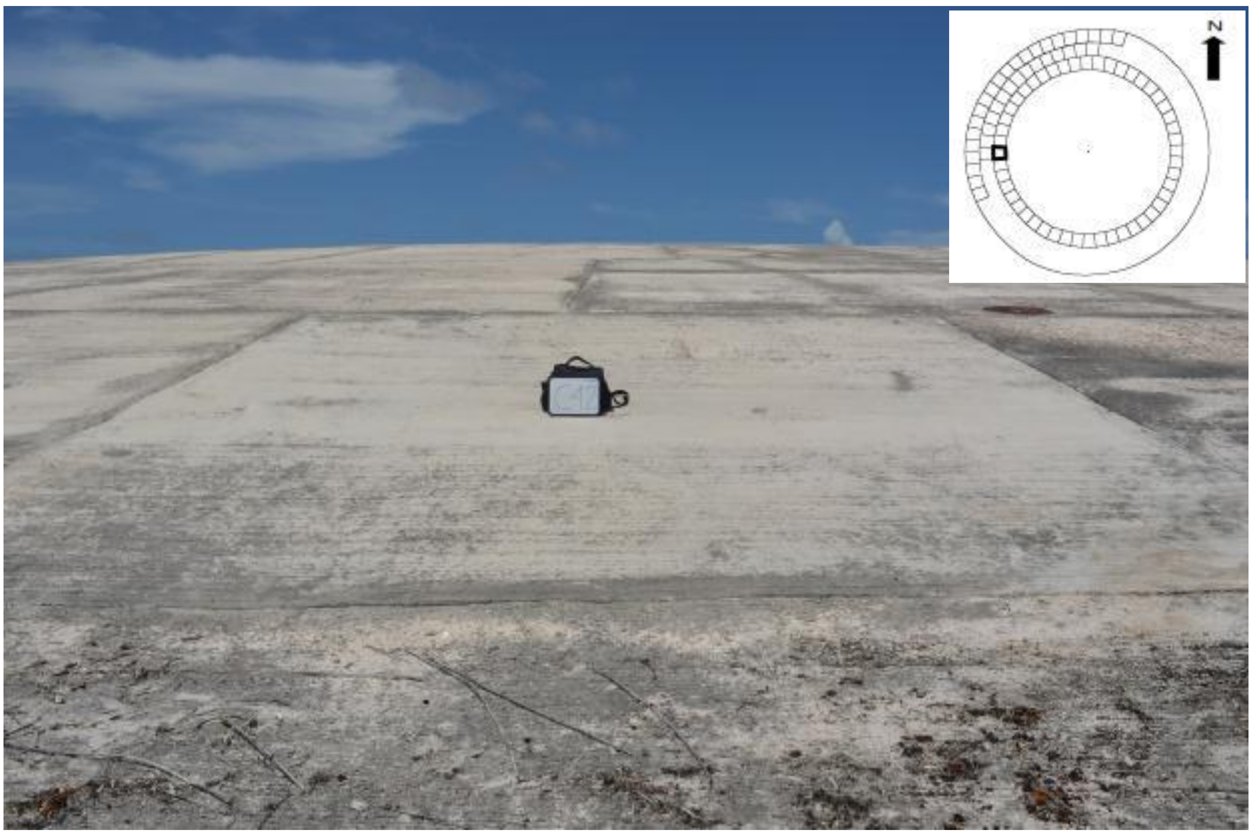
The panel has a rough and weathered appearance across the upper portion of the panel. Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. Rooting vegetation removed from along the panel seams. Surface crack observed extending up from a central location along the bottom seam up to a distance of about 2 meters away from the top of the panel.



CAP SECTION LOCATION: Panel C42

Description

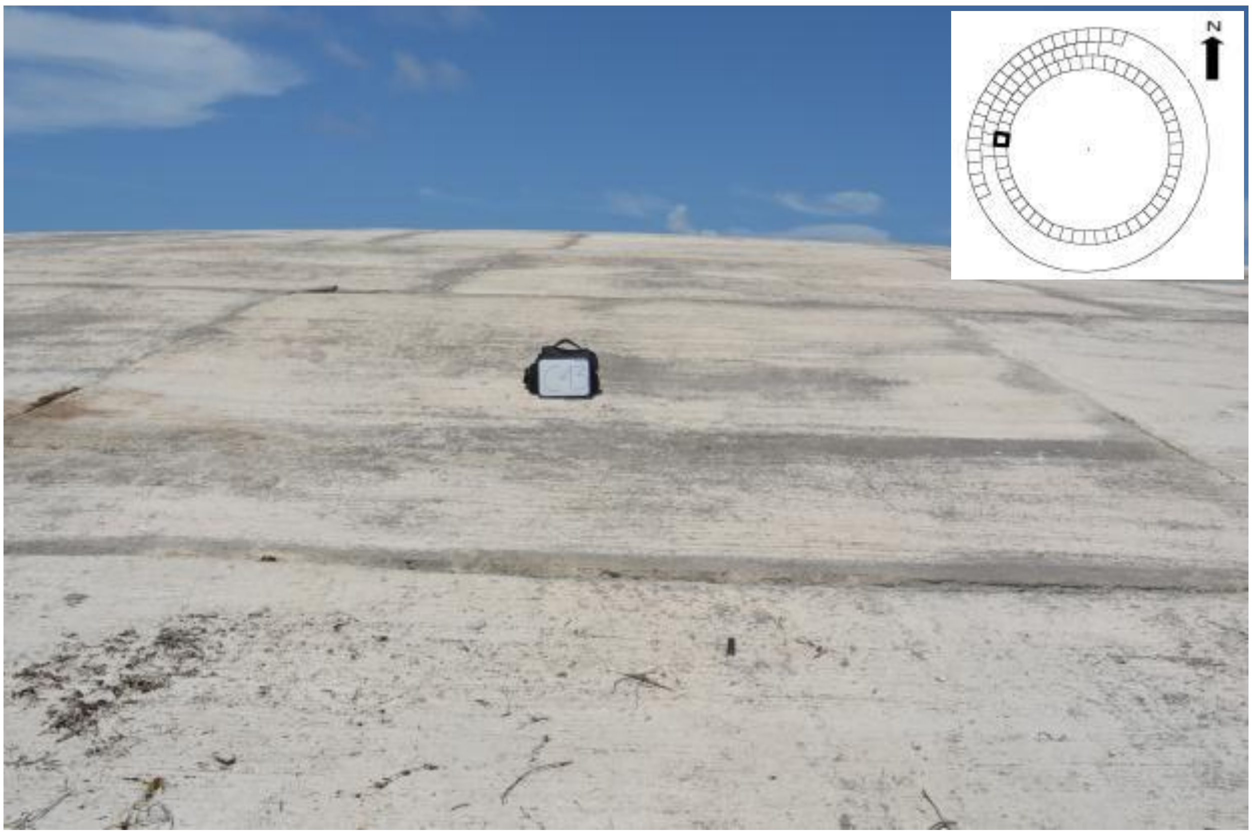
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel C43

Description

Significant spalling of concrete observed in the upper left corner of the panel where the chipped out piece of concrete extends down to contaminated soil – cement grout waste pile mixture below. Some minor spalling/cracking of concrete also observed in the lower right-hand corner of the panel. Panel recommended for priority repair.



CAP SECTION LOCATION: Panel C44

Description

No significant or obvious interior cracks extending across the top of the panel. Spalling/cracking of concrete observed along the bottom seam adjacent the intersecting corner between panel B56 and B57. Some spalling/cracking of concrete observed in the upper left-hand corner of the panel.

CAP SECTION LOCATION: Panel C45

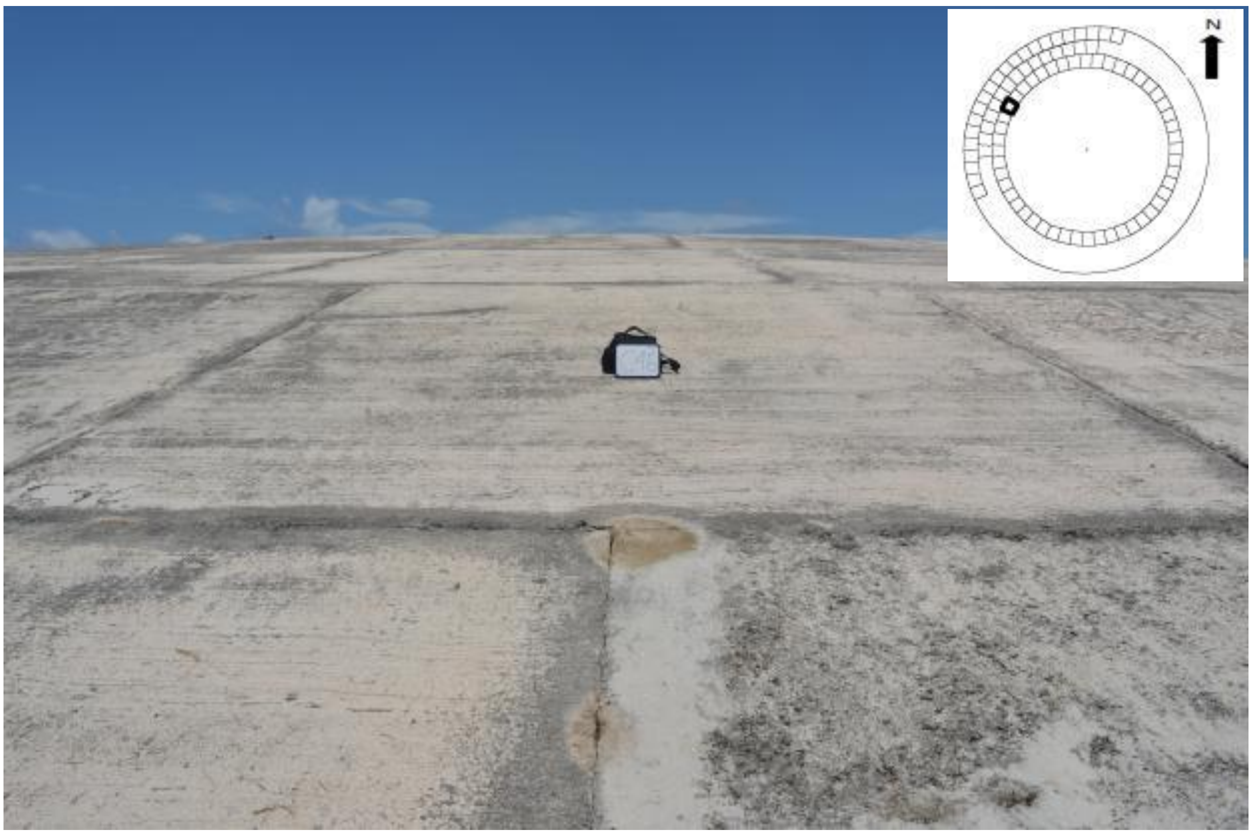
Description

The panel has a rough and weathered appearance. Also, the cracks along the panel joints appear to be deeper and more obvious compared with those appearing around panels on adjacent ring rows. A visible crack can be seen originating at intersecting corner between panel B57 and B58 on the bottom seam and extending up the panel for a distance of about 1 meter There is also an visible crack traversing across the panel.

CAP SECTION LOCATION: Panel C46

Description

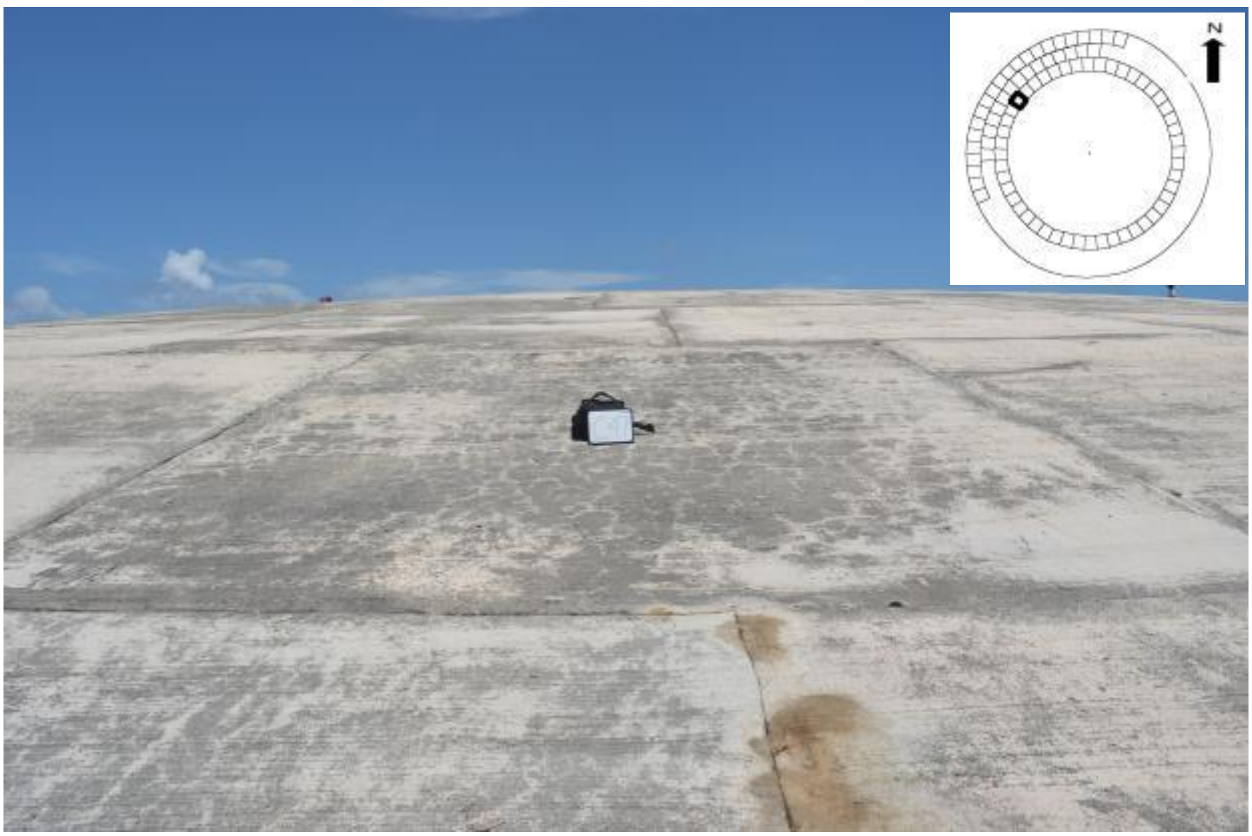
No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Some spalling/cracking of concrete observed in the upper left-hand corner of the panel.



CAP SECTION LOCATION: Panel C47

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. The cracks along the panel joints appear to be deeper and more obvious compared with those appearing around panels on adjacent ring rows. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel C48

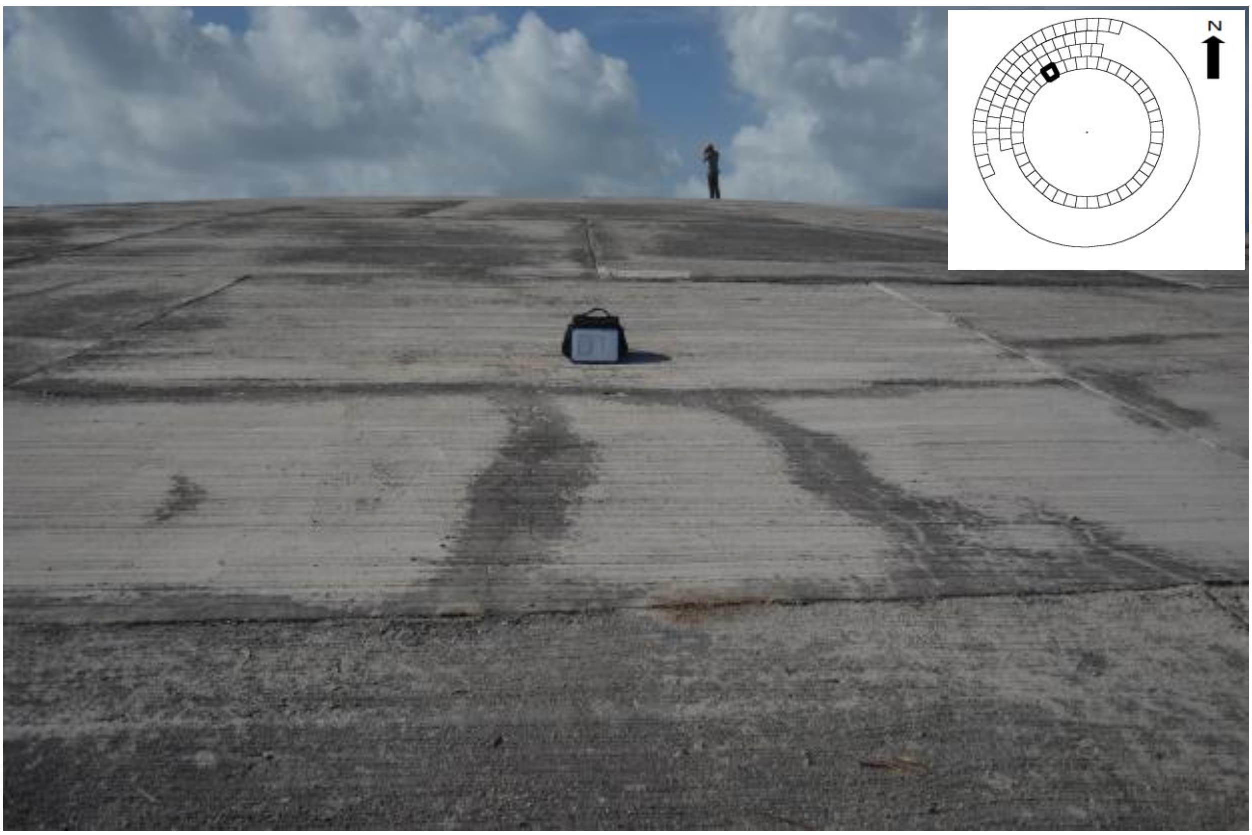
Description

No significant or obvious interior cracks extending across the top of the panel. The cracks along the panel joints appear to be deeper and more obvious compared with those appearing around panels on adjacent ring rows. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel D1

Description

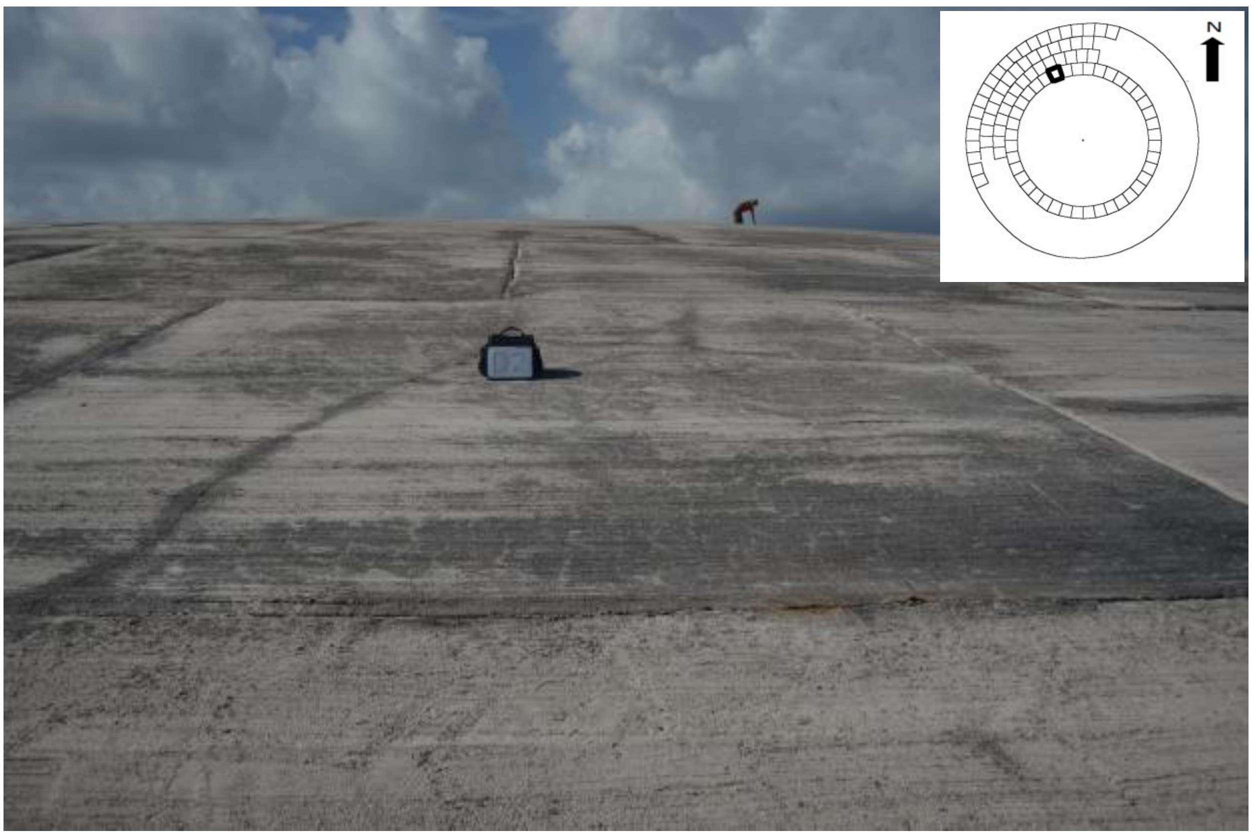
Two main surface cracks extending up from the bottom seam intersecting with another crack traversing across the segment at about a mid-point up the panel. Rooting vegetation removed from along the panel seams. Minor spalling/cracking of concrete observed in the lower left-hand corner of the panel.



CAP SECTION LOCATION: Panel D2

Description

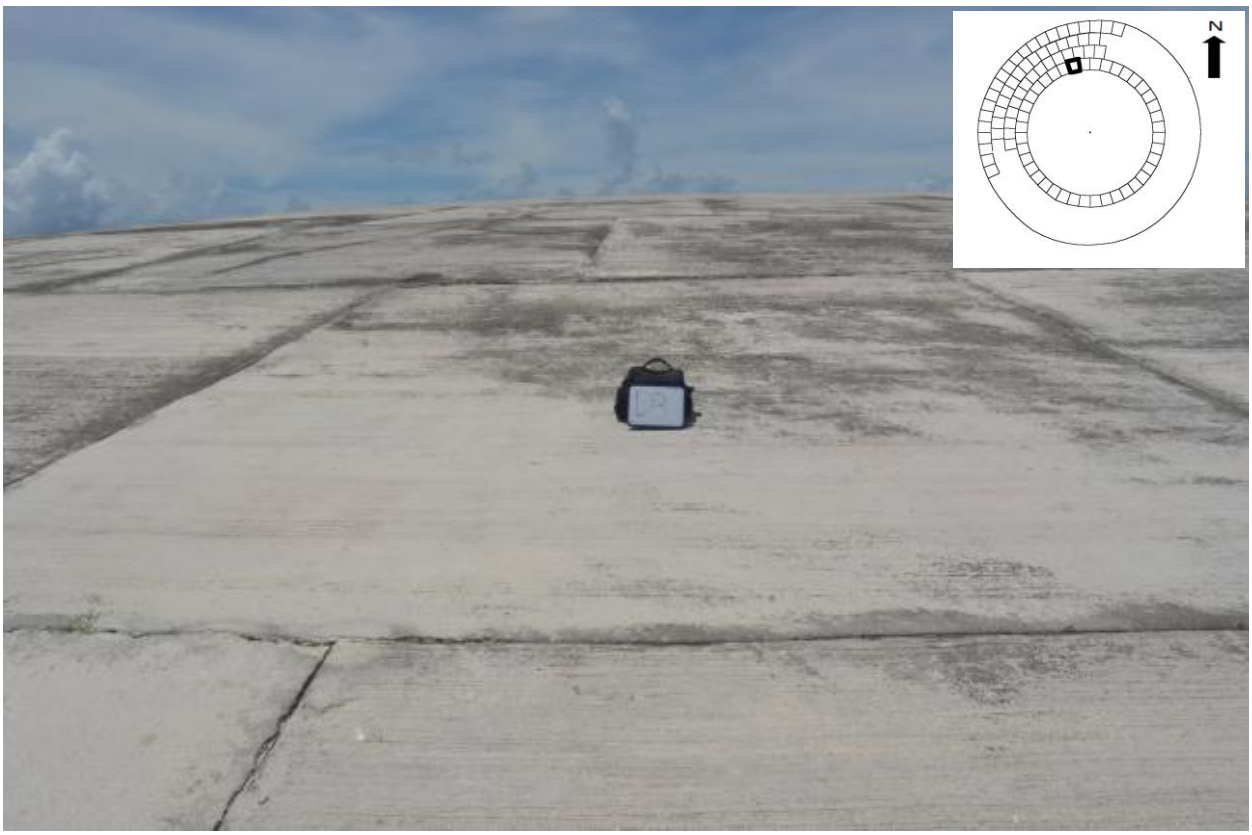
Rooting vegetation removed from along the panel seams. Surface crack observed extending from left side of the bottom seam traveling up towards the upper seam intersecting at corner E1/E36 on the ring row above with a fork branching out to the left and right sides of the panel.



CAP SECTION LOCATION: Panel D3

Description

No significant or obvious interior cracks extending across the top of the panel. The upper portion of the panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams. Some spalling/cracking of concrete observed in the upper left-hand corner of the panel with some indication that some post-construction work was conducted in an apparent attempt to repair the spall.



CAP SECTION LOCATION: Panel D4

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams. Panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel D5

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Some spalling/cracking of concrete observed in the lower right-hand corner of the panel. Rooting vegetation removed from along the panel seams. Panel contains a filled concrete bore-hole (CD-1) from the 1980 NAS investigation.

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CAP SECTION LOCATION: Panel D6

Description

A surface crack observed extending across the segment at mid-point up the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel D7

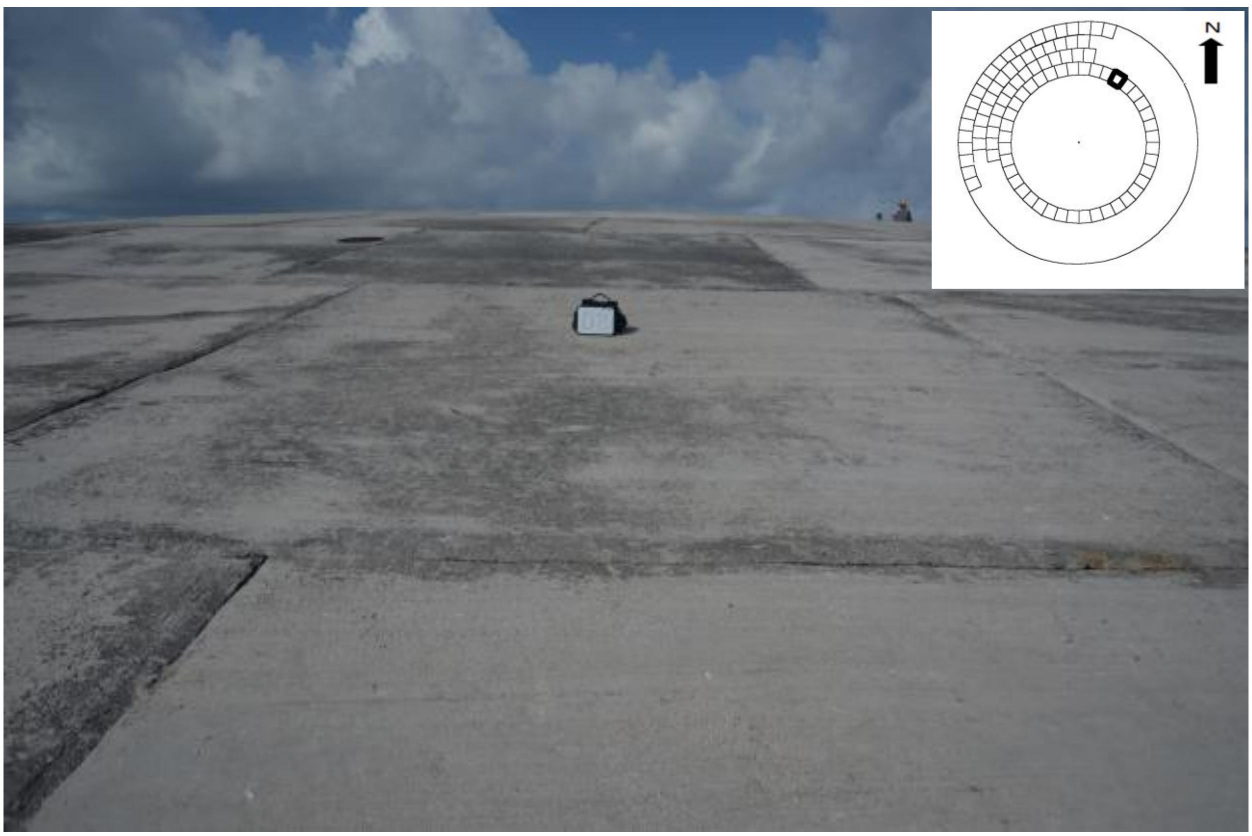
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel D8

Description

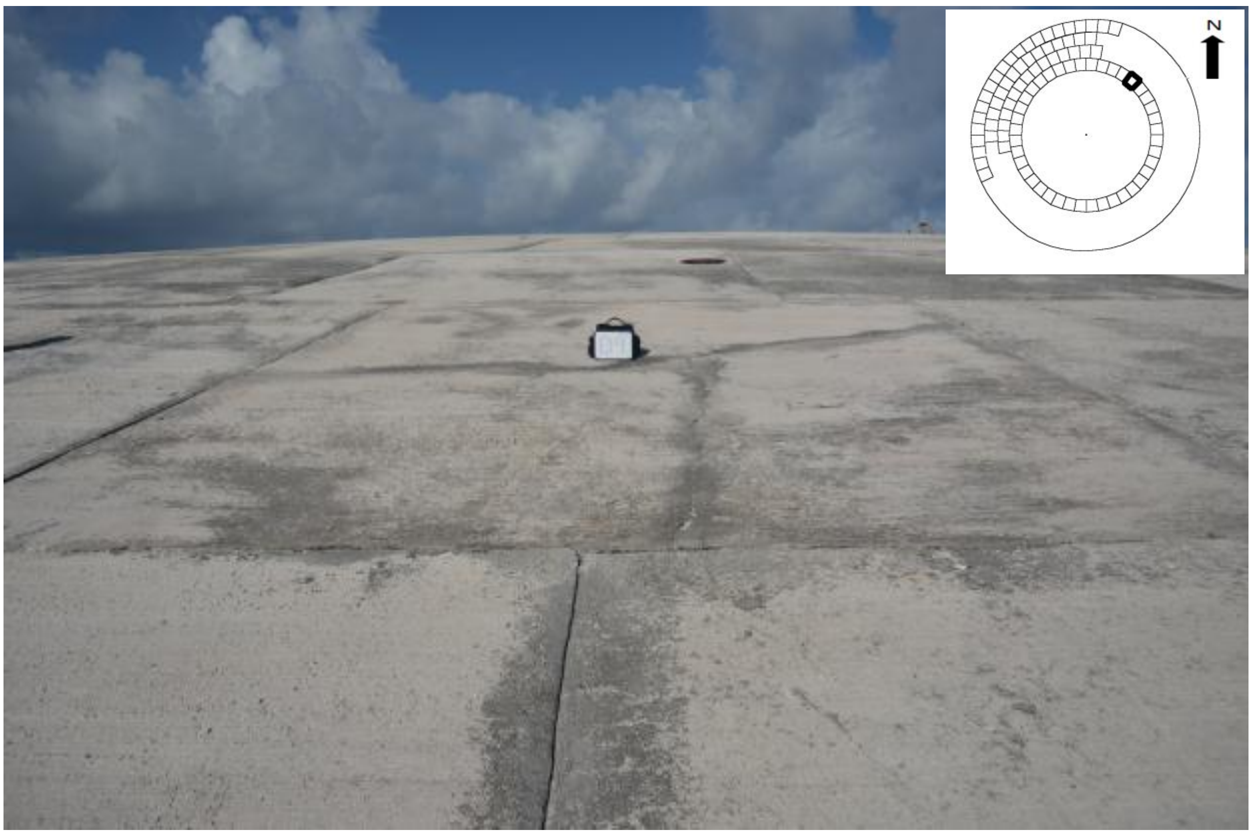
No significant or obvious interior cracks extending across the top of the panel. The lower left side of the panel has a weathered appearance. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel D9

Description

The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams. A surface crack observed extending from the bottom seam branching into fork at about the mid-point up the panel out to the left and right edges.



CAP SECTION LOCATION: Panel D10

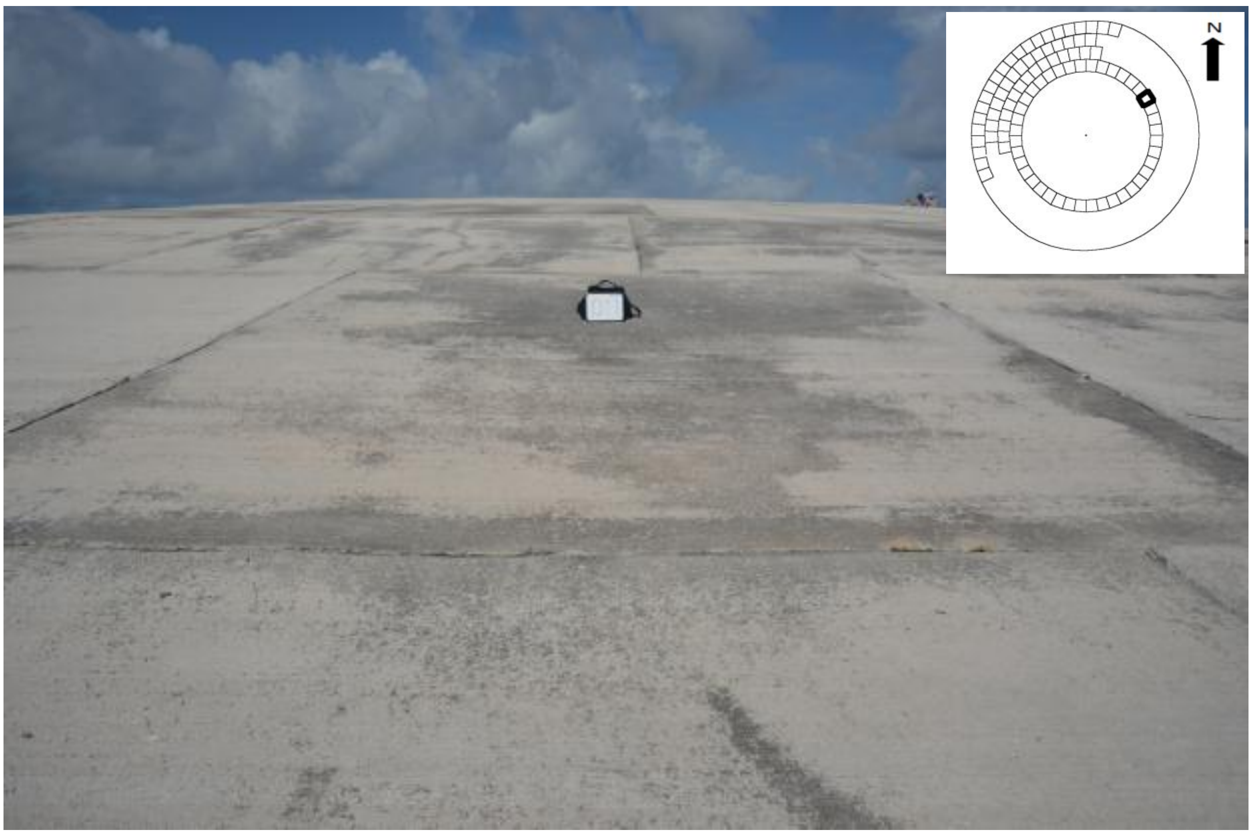
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams. Some minor spalling/cracking of concrete observed along the right side of the bottom seam.

CAP SECTION LOCATION: Panel D11

Description

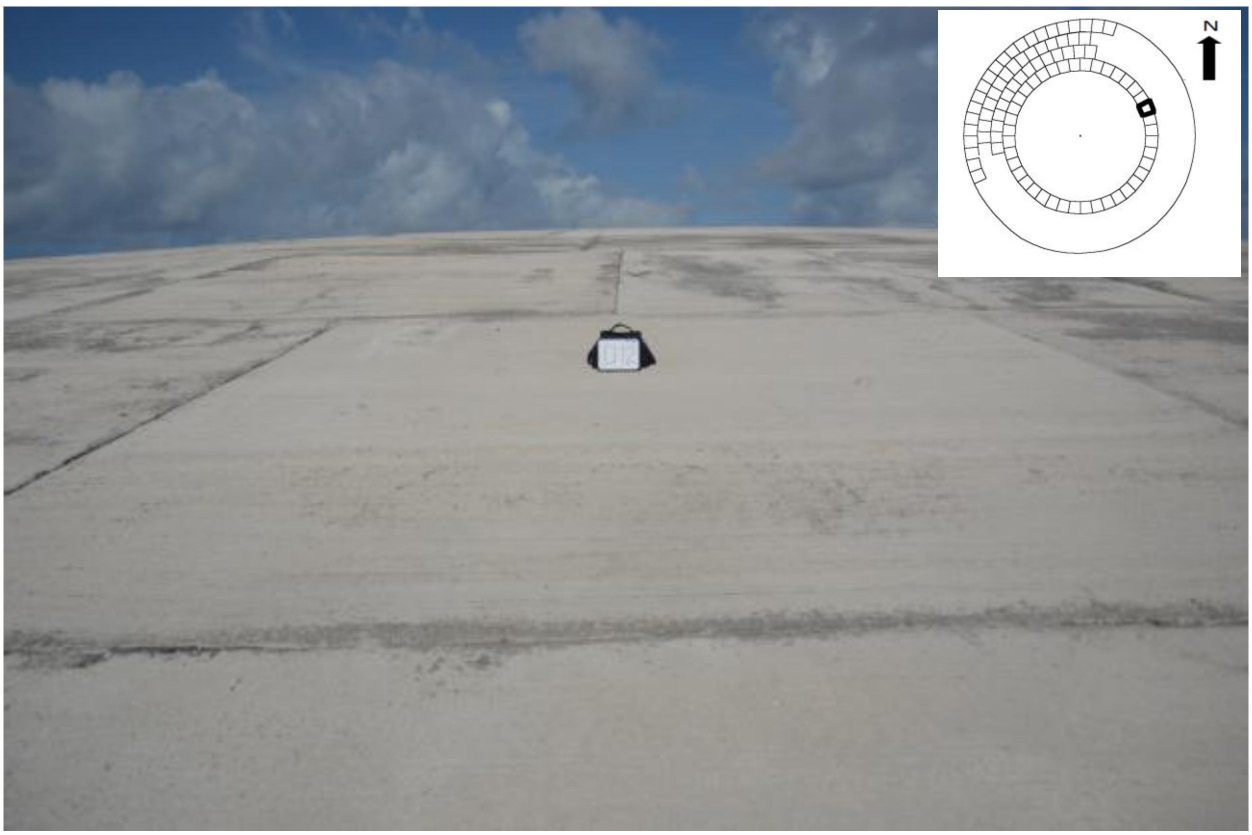
No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel D12

Description

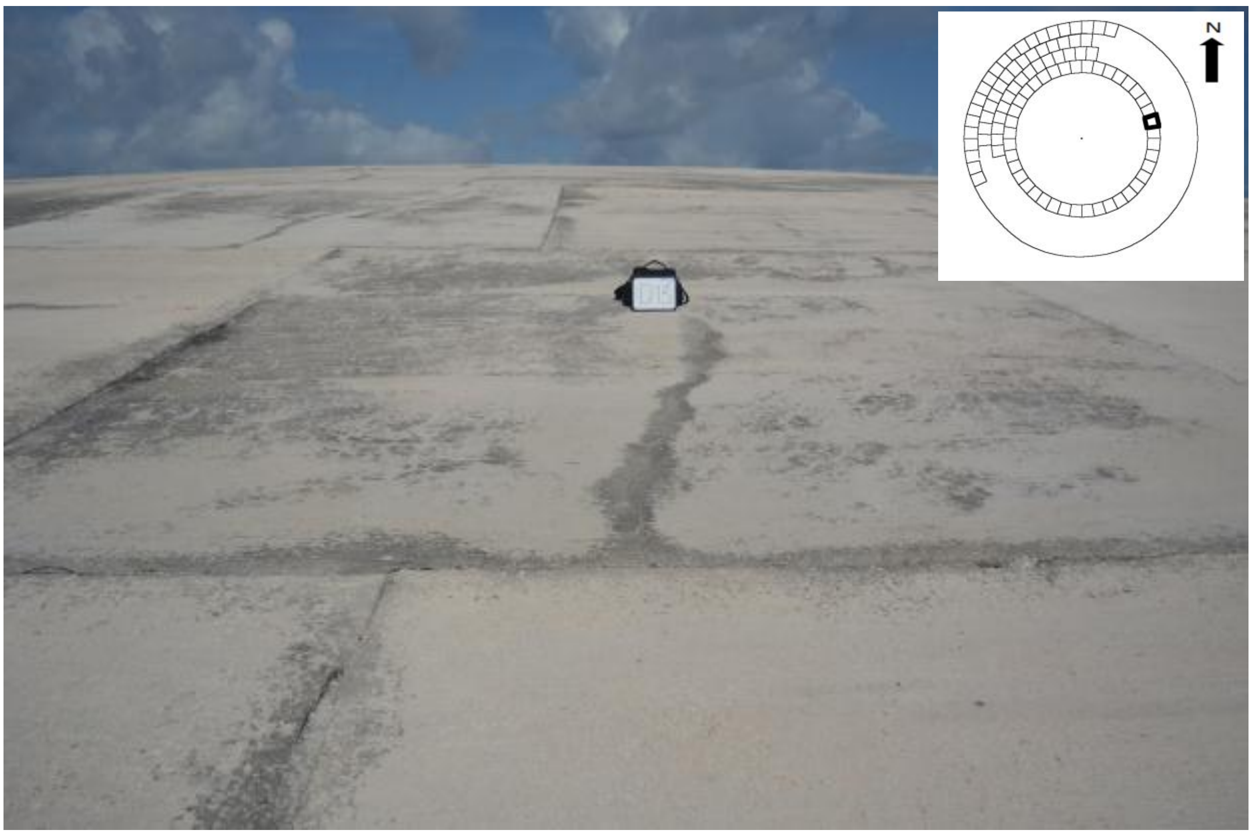
No obvious interior cracks extending across the top of the panel. Some spalling/cracking of concrete observed in the lower right-hand corner of the panel.



CAP SECTION LOCATION: Panel D13

Description

The panel has a rough and weathered appearance. Surface crack observed extending up from the bottom seam on top edge adjacent to corner intersection E10/E11.



CAP SECTION LOCATION: Panel D14

Description

The panel has a rough and weathered appearance. A surface crack observed extending up from bottom seam adjacent to the corner intersection C17/C18. Panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel D15

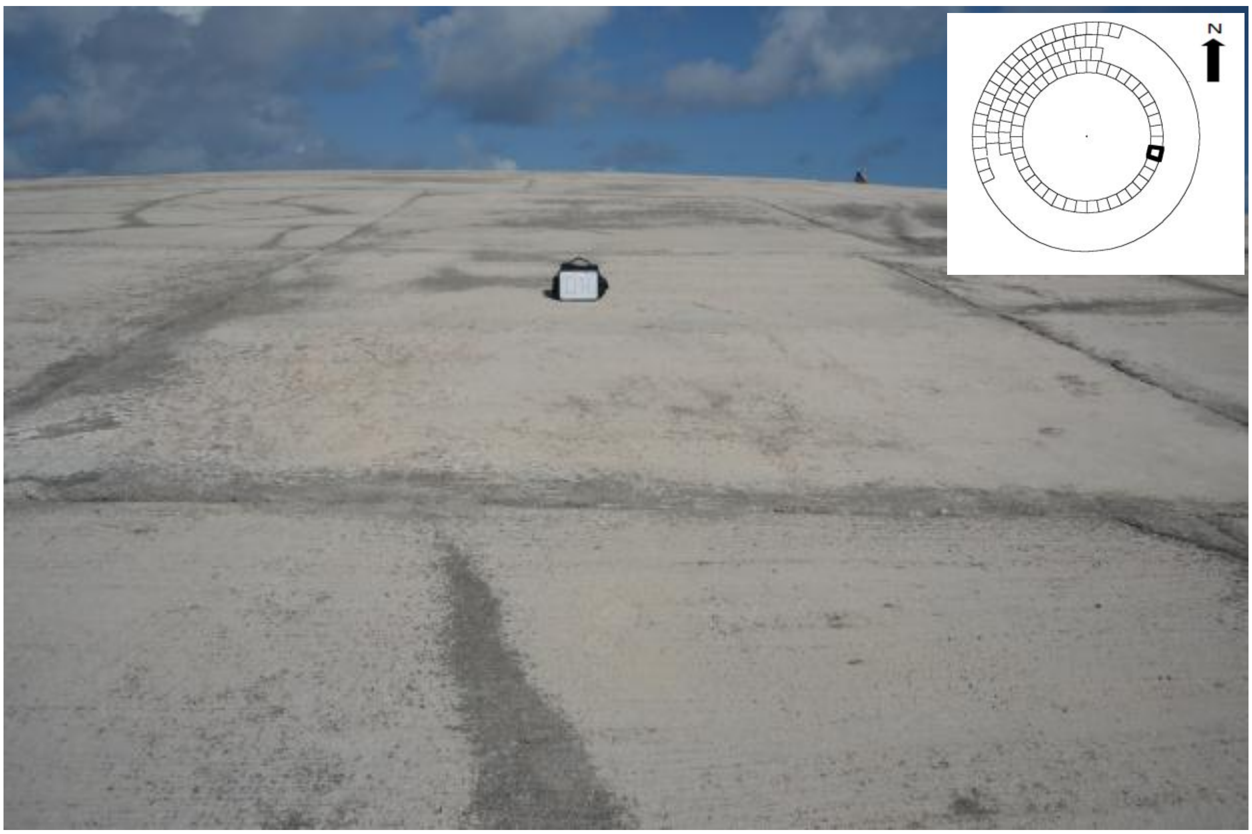
Description

This panel contains the most severe crack of any segment on the dome. The crack width exceeds several millimeters in some areas, and runs left to right at about a mid-point up the panel as well as up and down the panel from an intersection point in the middle. The crack contained chipped ‘spalled’ edges. Panel is listed as a priority for any repair work.

CAP SECTION LOCATION: Panel D16

Description

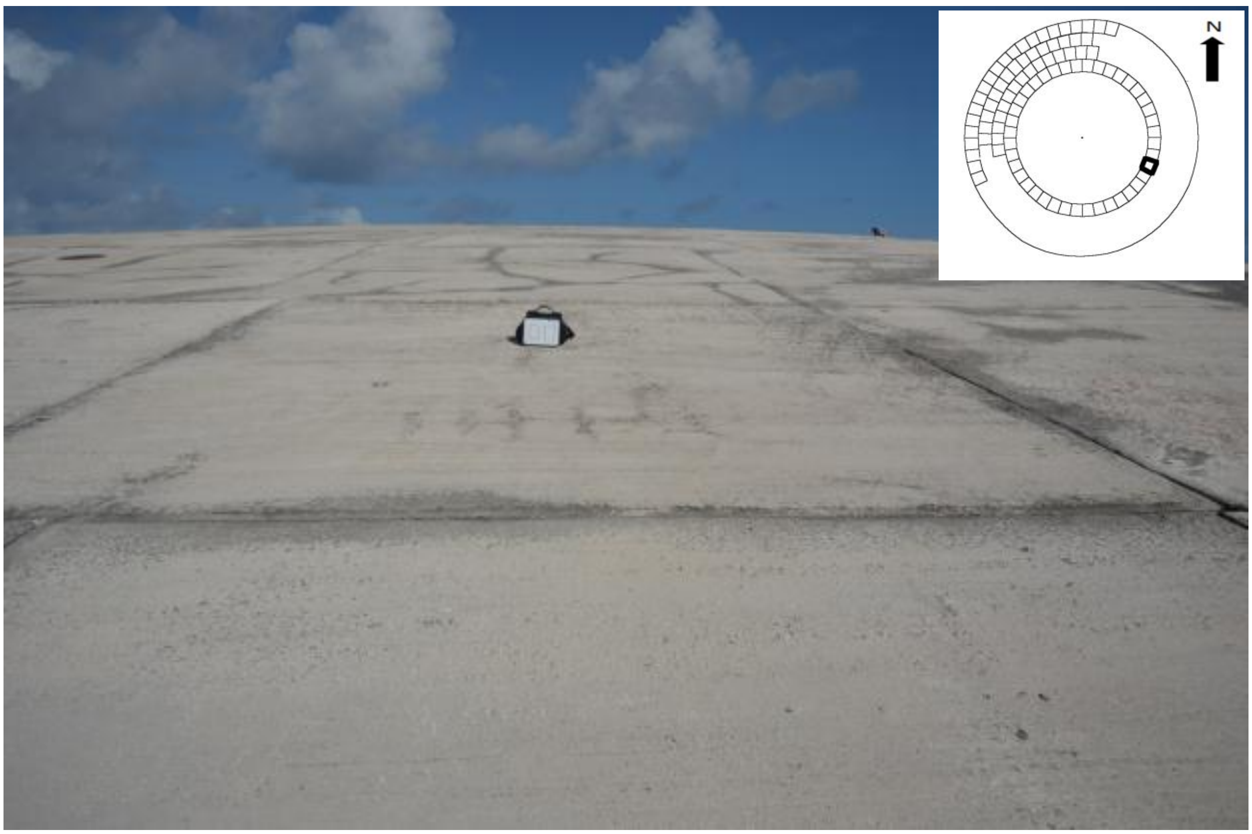
No obvious interior cracks extending across the top of the panel. Some spalling/cracking of concrete observed along the lower seam on both the left and right sides of the panel.



CAP SECTION LOCATION: Panel D17

Description

No obvious interior cracks extending across the top of the panel. Some spalling/cracking of concrete observed in the bottom left corner and along lower seam adjacent to the intersecting corner between panel C21 and C22 on the left side of the panel.



CAP SECTION LOCATION: Panel D18

Description

No obvious interior cracks extending across the top of the panel. Some spalling/cracking of concrete observed in the right-hand corner of the panel. Panel labels D19 and D20 were skipped.

CAP SECTION LOCATION: Panel D21

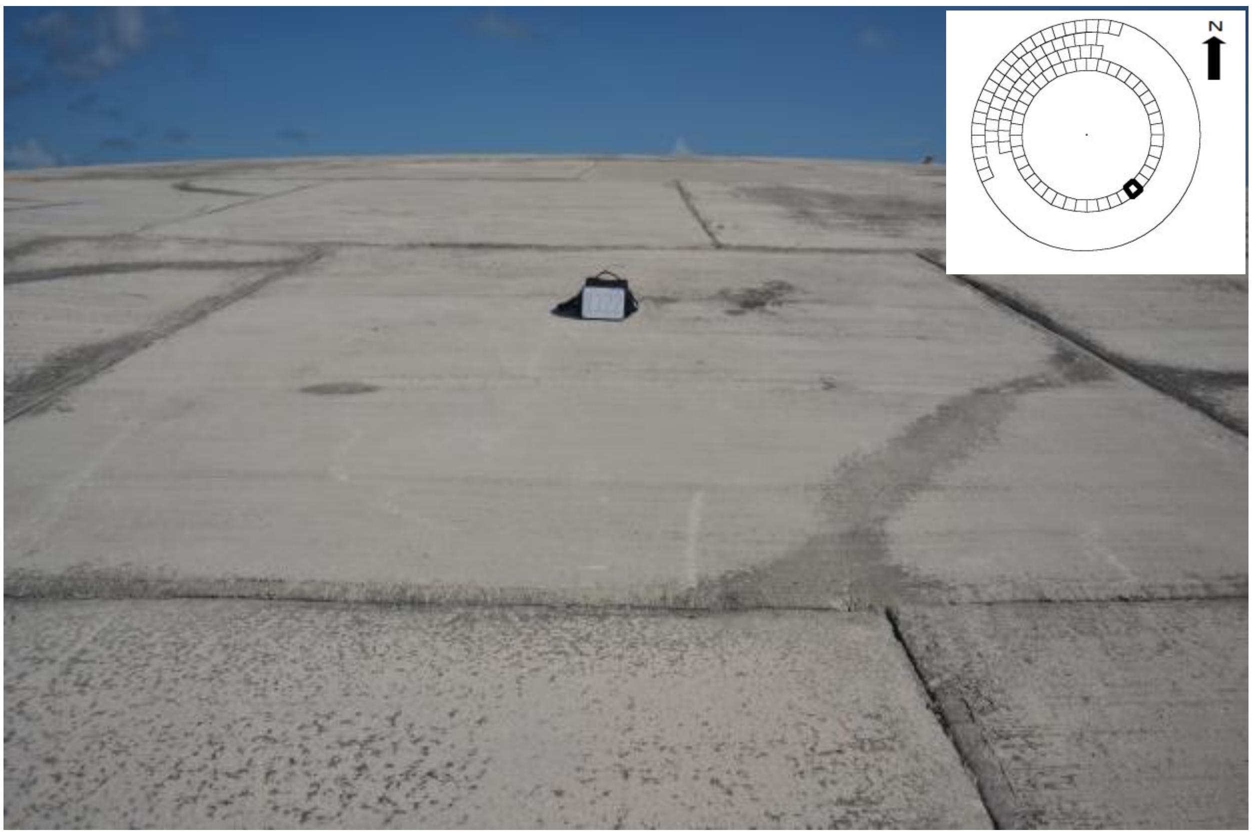
Description

A crack observed extending upwards from a central position along the bottom seam adjacent to corner intersection C22/C23 and intersecting at corner E15/E16 on the ring row above. The crack branches out into a fork to the left edge at distances between 2 and 3 meters up from the base of the panel. The crack contains chipped ‘spalled” edges. Panel is recommended as a priority for repair!

CAP SECTION LOCATION: Panel D22

Description

A surface crack observed originating from the corner intersection C22/C25 along the bottom seam and intersecting with the right edge of the panel at a distance of about 3 meters up from the base of the panel. Some spalling/cracking of concrete observed in the lower left-hand corner and along the upper left edge of the panel.



CAP SECTION LOCATION: Panel D23

Description

The panel contains a crisscross crack intersecting with the bottom right, lower left, upper right and central upper seams of the panel. The crack has chipped "spalled" edges. Panel recommended for priority repair.

CAP SECTION LOCATION: Panel D24

Description

No significant or obvious interior cracks extending across the top of the panel.

CAP SECTION LOCATION: Panel D25

Description

No significant or obvious interior cracks extending across the top of the panel. The upper portion of the panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel D26

Description

A minor surface crack observed extending up from a central position adjacent to the corner intersection C29/C30 on the ring row below for a distance of about 1 meter . The panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel D27

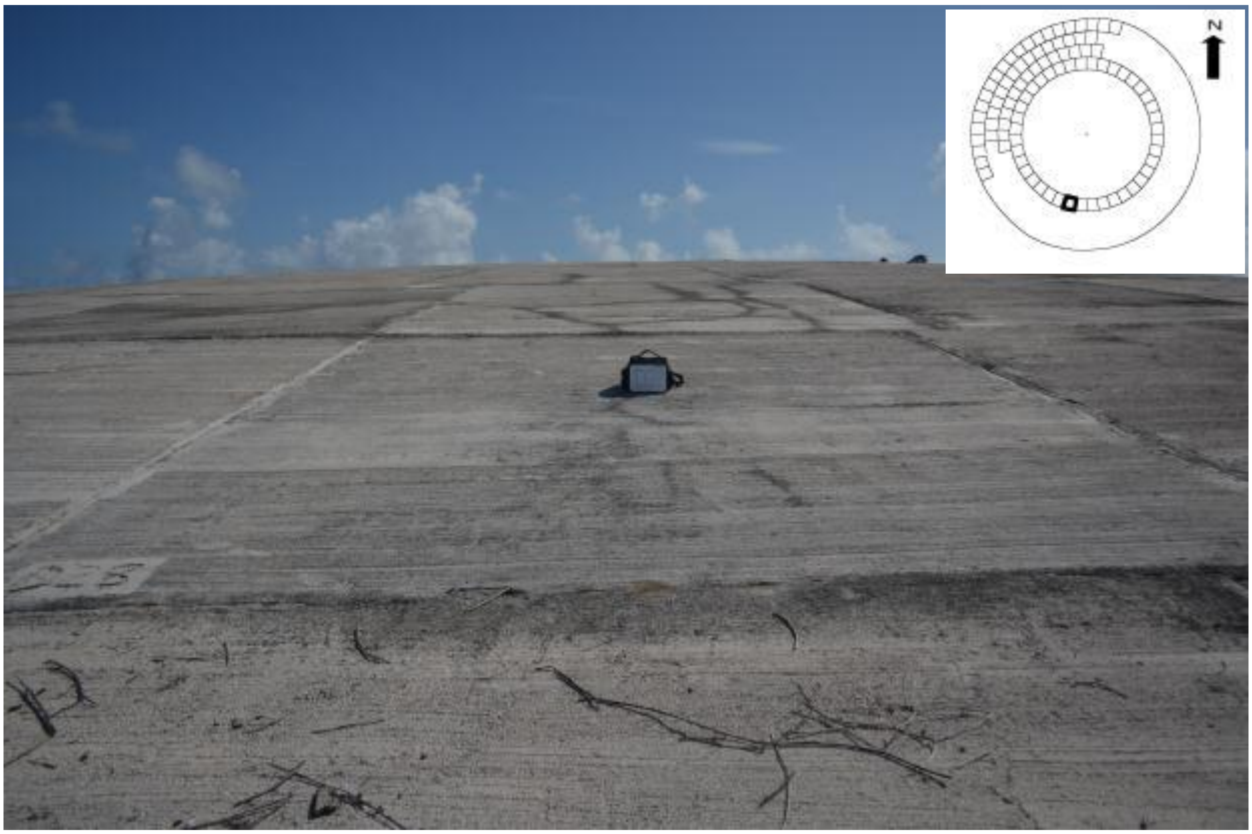
Description

The panel has a rough and weathered appearance. Some minor spalling/cracking of concrete observed along the right-hand side of the bottom seam. A surface crack observed running straight up the panel about 5 meters from a central position along the bottom seam.

CAP SECTION LOCATION: Panel D28

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel D29

Description

The upper portion of the panel has a rough and weathered appearance. A minor surface crack observed traversing across the upper portion of the panel.

CAP SECTION LOCATION: Panel D30

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel D31

Description

The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams. A surface crack observed traversing across the left corner of the panel intersecting the bottom and left seams about 2.5 to 3 meters away from the corner of the panel.

CAP SECTION LOCATION: Panel D32

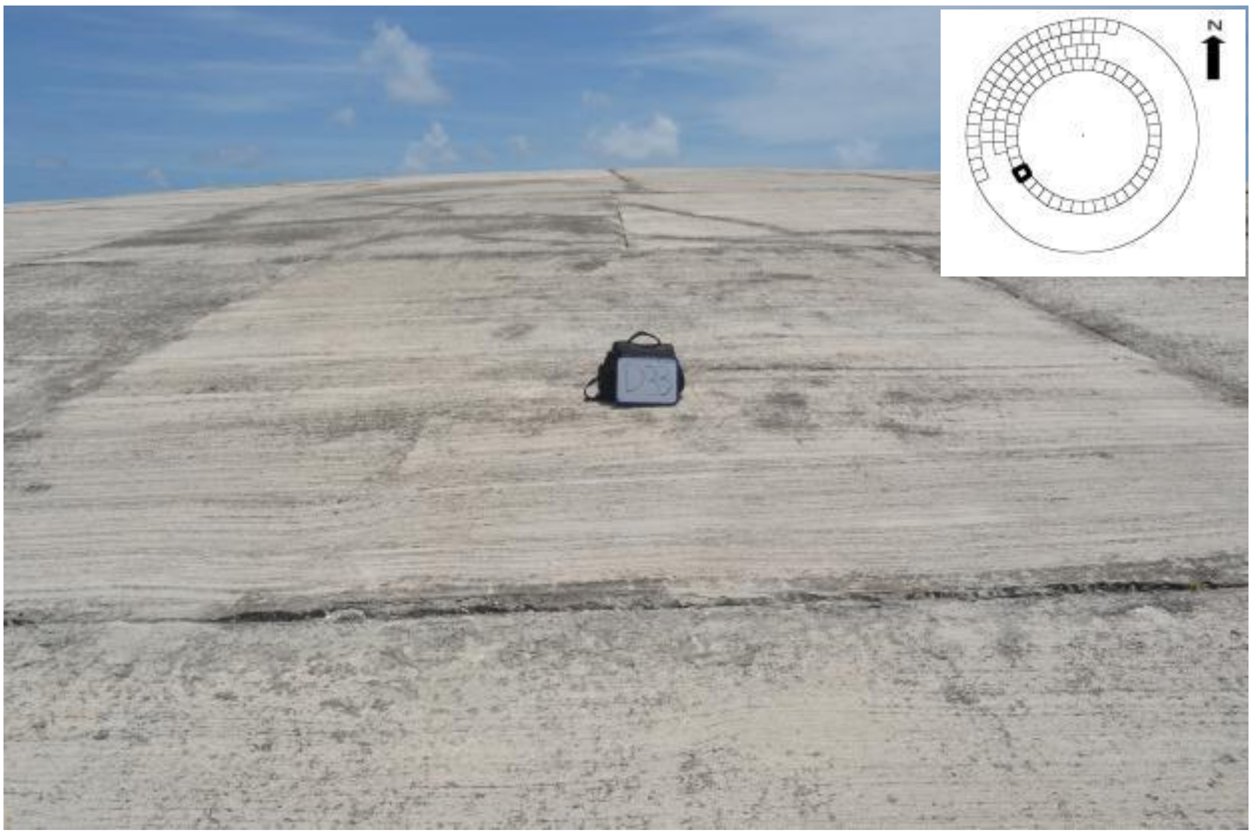
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel D33

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance.



CAP SECTION LOCATION: Panel D34

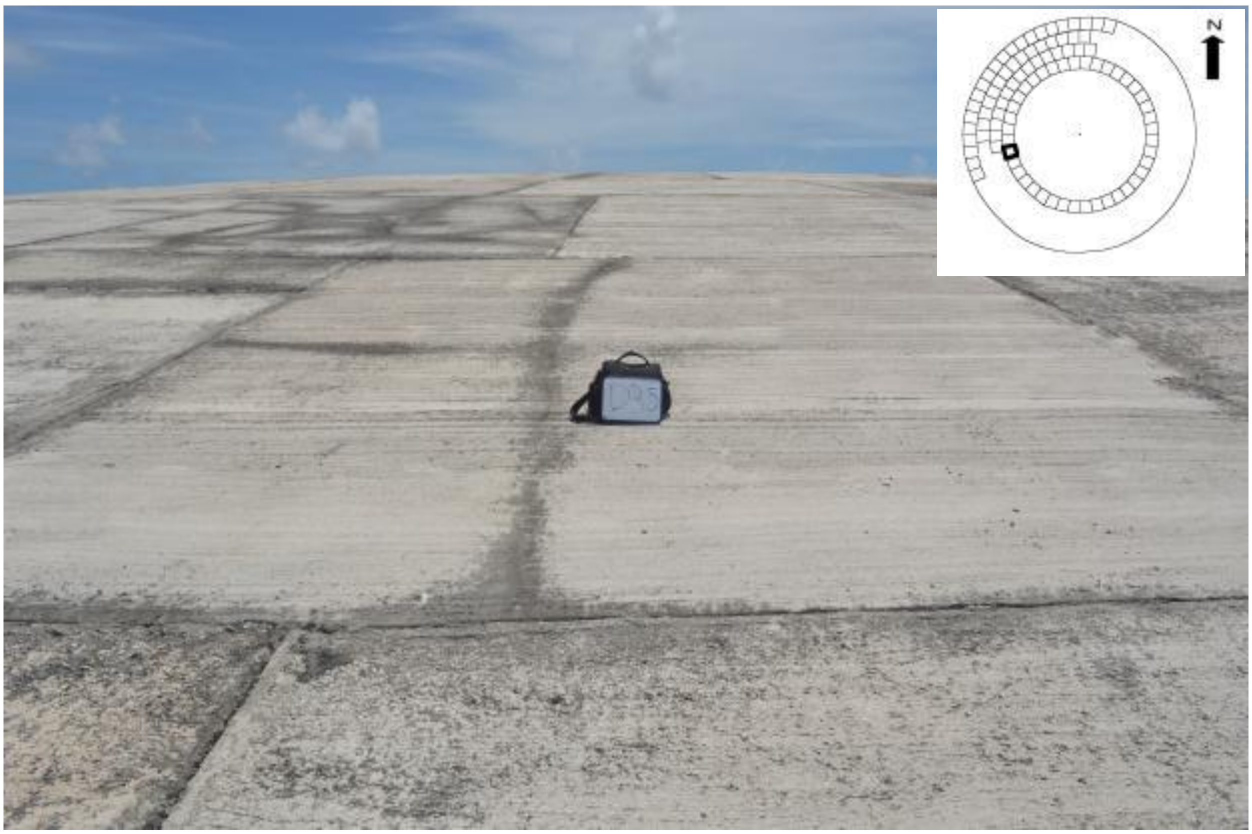
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel D35

Description

Some spalling/cracking of concrete observed in the lower left-hand corner of the panel. Rooting vegetation removed from along the panel seams. A surface crack observed extending up from a central position along the bottom seam intersecting the upper seam adjacent corner E28/E29 on the ring row above with a branch off to the left side at a mid-point up the panel.



CAP SECTION LOCATION: Panel D36

Description

The panel has a rough and weathered appearance. There is a significant crack traversing across the panel at a distance of above 1.5 to 2 meters from the top seam. The crack crisscrosses downwards from a position on the upper seam to the right side of corner intersection E29/E30 on the ring row above, and interacting with the lower seam at a point adjacent to corner intersection C42/C42 on the ring row below. Panel contains a vertical elevation benchmark. The cracks have chipped “spalled” edges. It is recommended that the cracks receive priority for repair!

CAP SECTION LOCATION: Panel D37

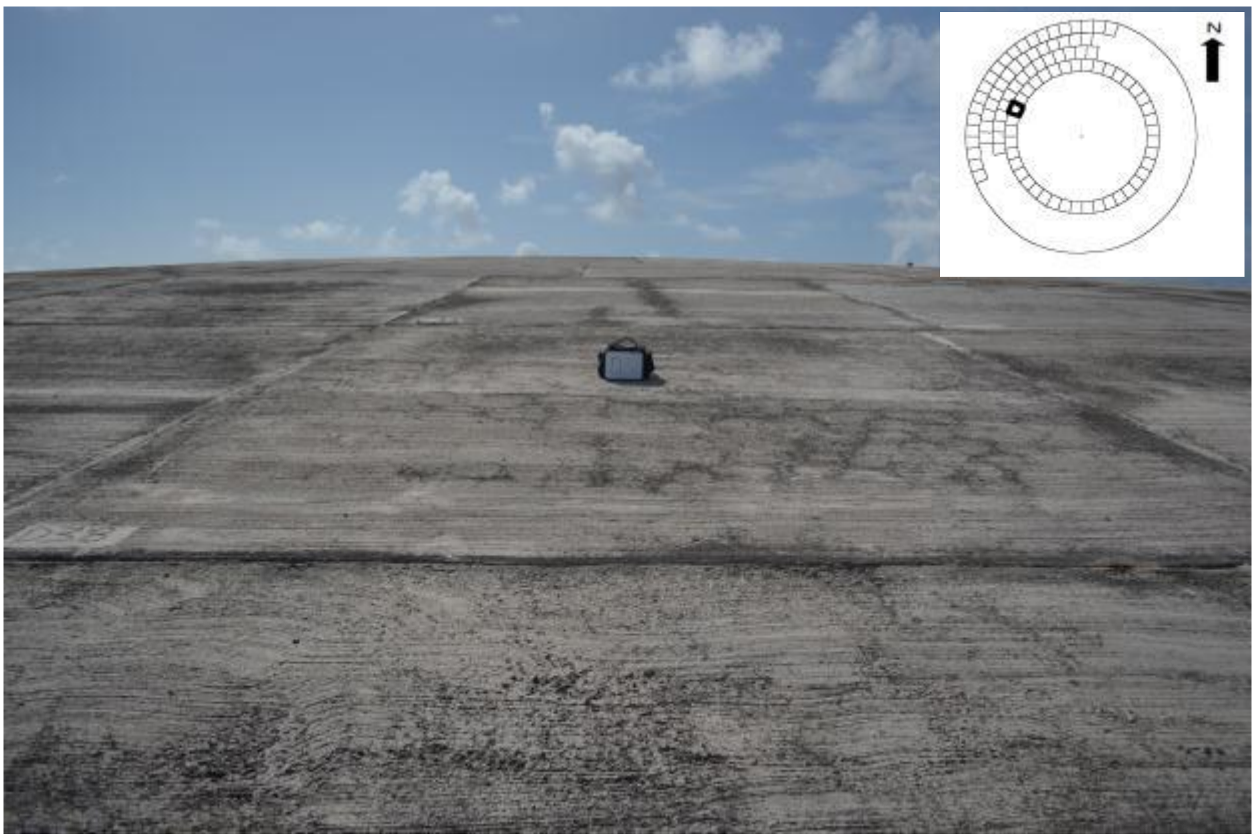
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a slightly more rough and weathered appearance. Some spalling/cracking of concrete observed along the right side of the bottom seam.

CAP SECTION LOCATION: Panel D38

Description

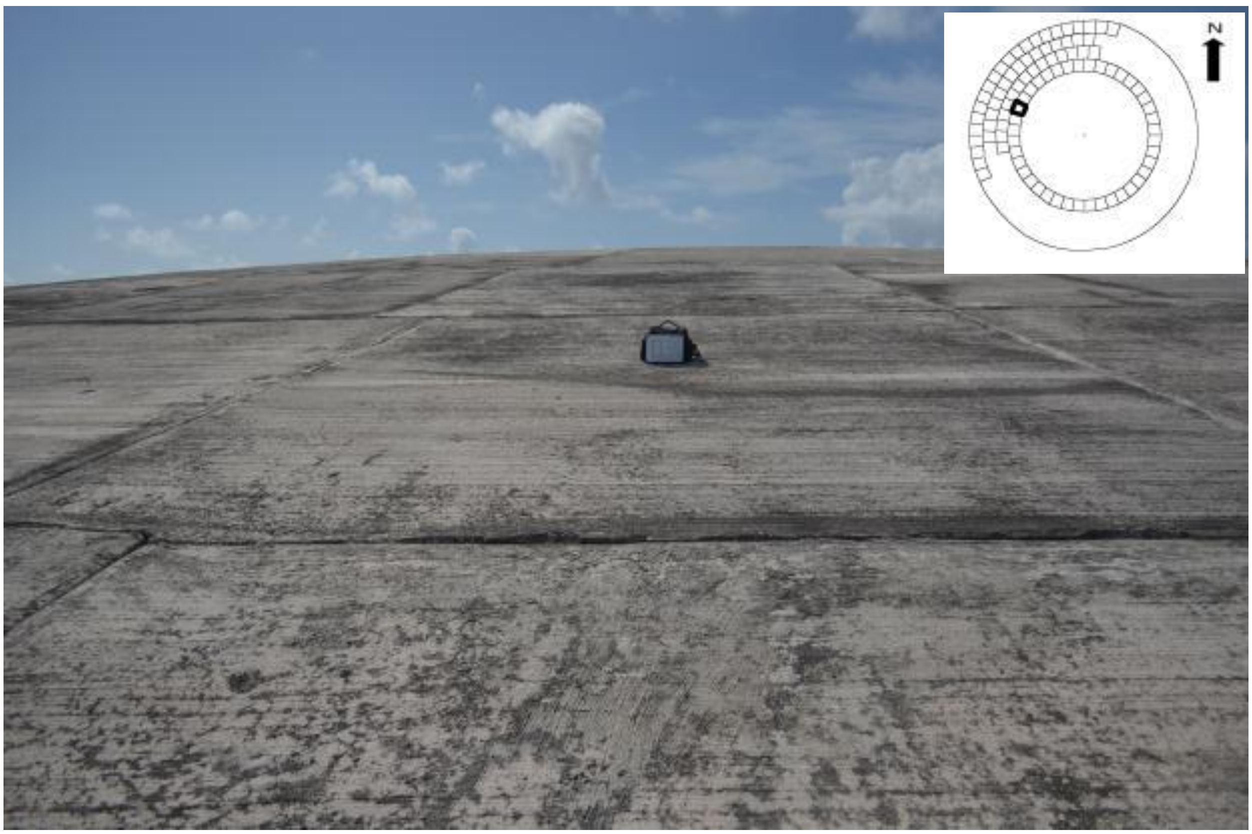
No significant or obvious interior cracks extending across the top of the panel. The panel has a slightly more rough and weathered appearance. Some spalling/cracking of concrete observed in the upper left-hand corner and along the right side of the upper seam of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel D39

Description

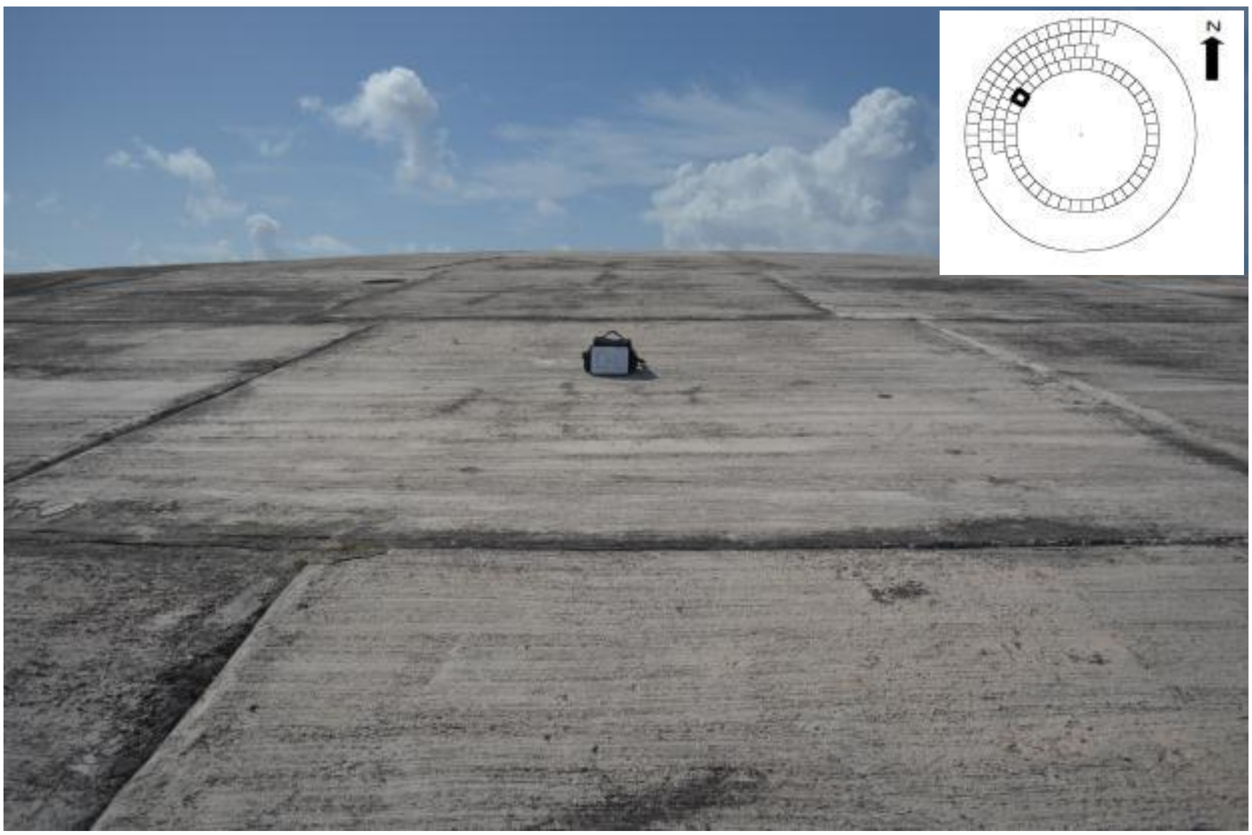
No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Some spalling/cracking of concrete observed in the upper and lower left corners.



CAP SECTION LOCATION: Panel D40

Description

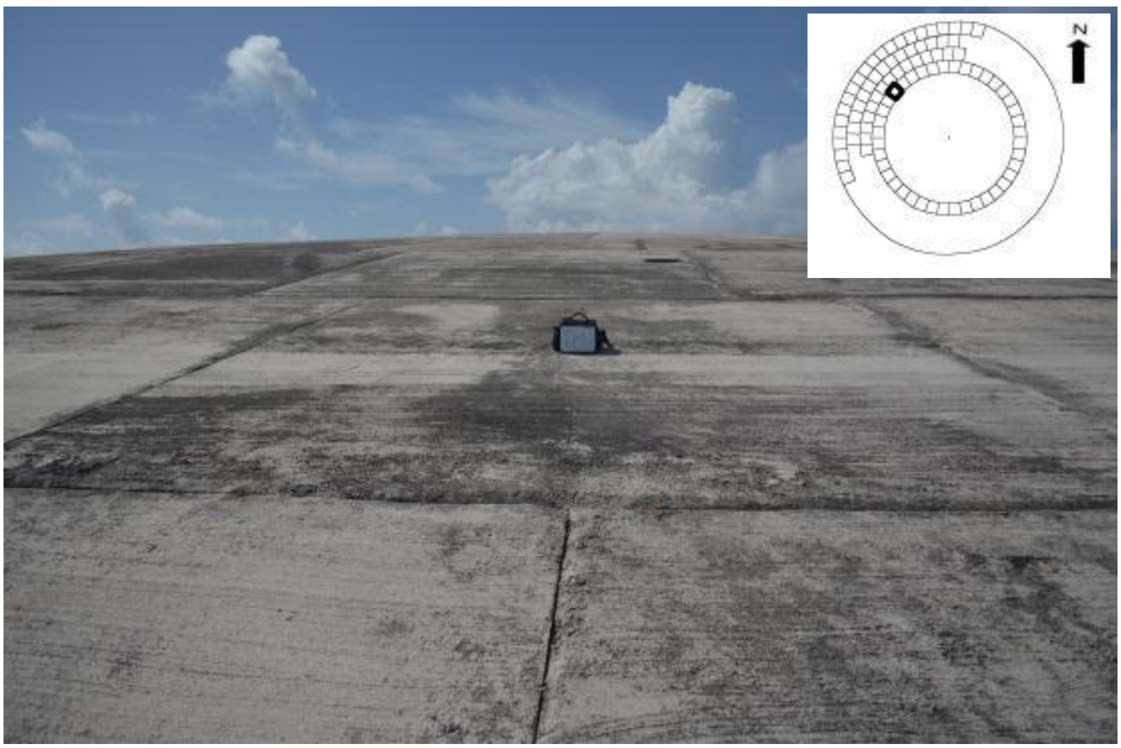
No significant or obvious interior cracks extending across the top of the panel. The panel has a slightly more rough and weathered appearance. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel D41

Description

Then panel has a rough and weathered appearance. Some spalling/cracking of concrete observed in the lower left-hand corner and along the left seam of the panel. A significant crack observed extending up through the middle of the panel from a central position along the bottom seam adjacent to the intersecting corner of panels on the ring row below. The crack has chipped “spalled” edges. The panel is recommended for priority repair.



CAP SECTION LOCATION: Panel D42

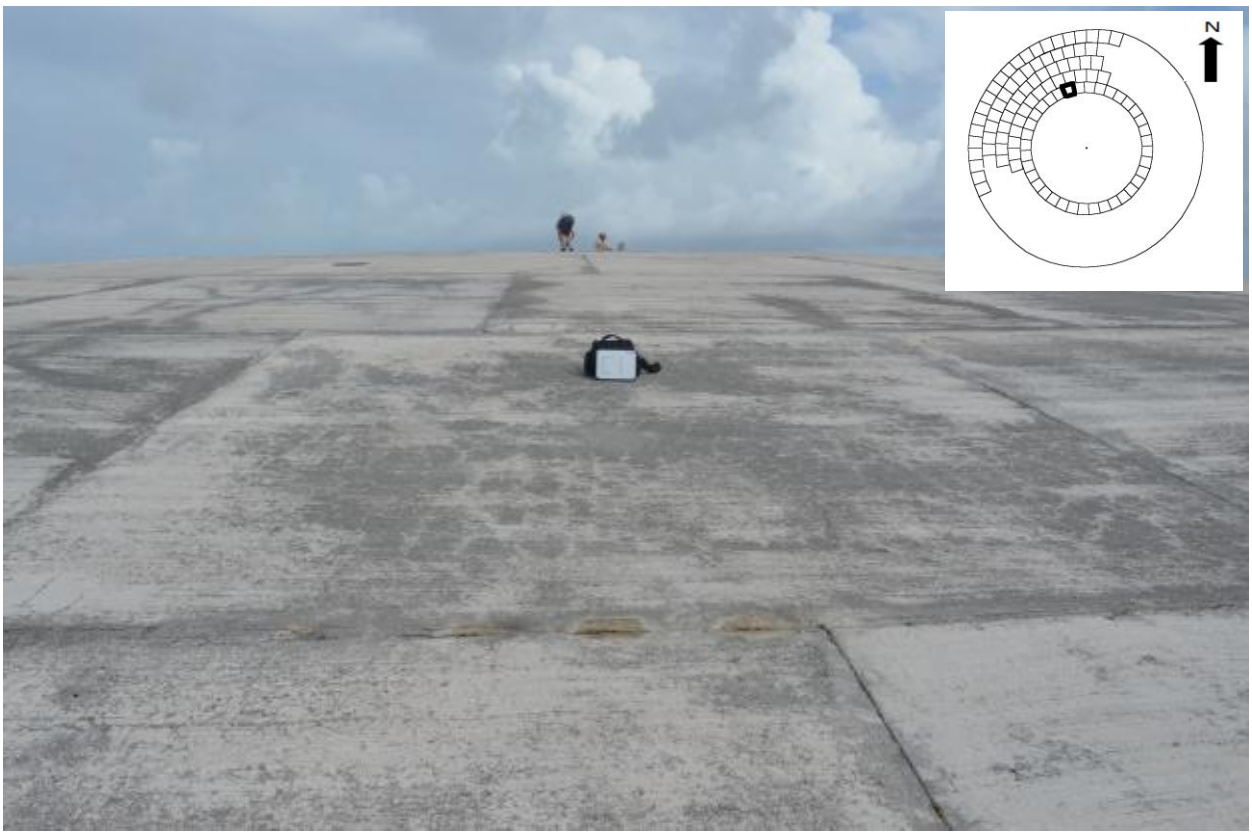
Description

No significant or obvious interior cracks extending across the top of the panel. Some minor spalling/cracking of concrete observed near the left corner of bottom beam

CAP SECTION LOCATION: Panel E1

Description

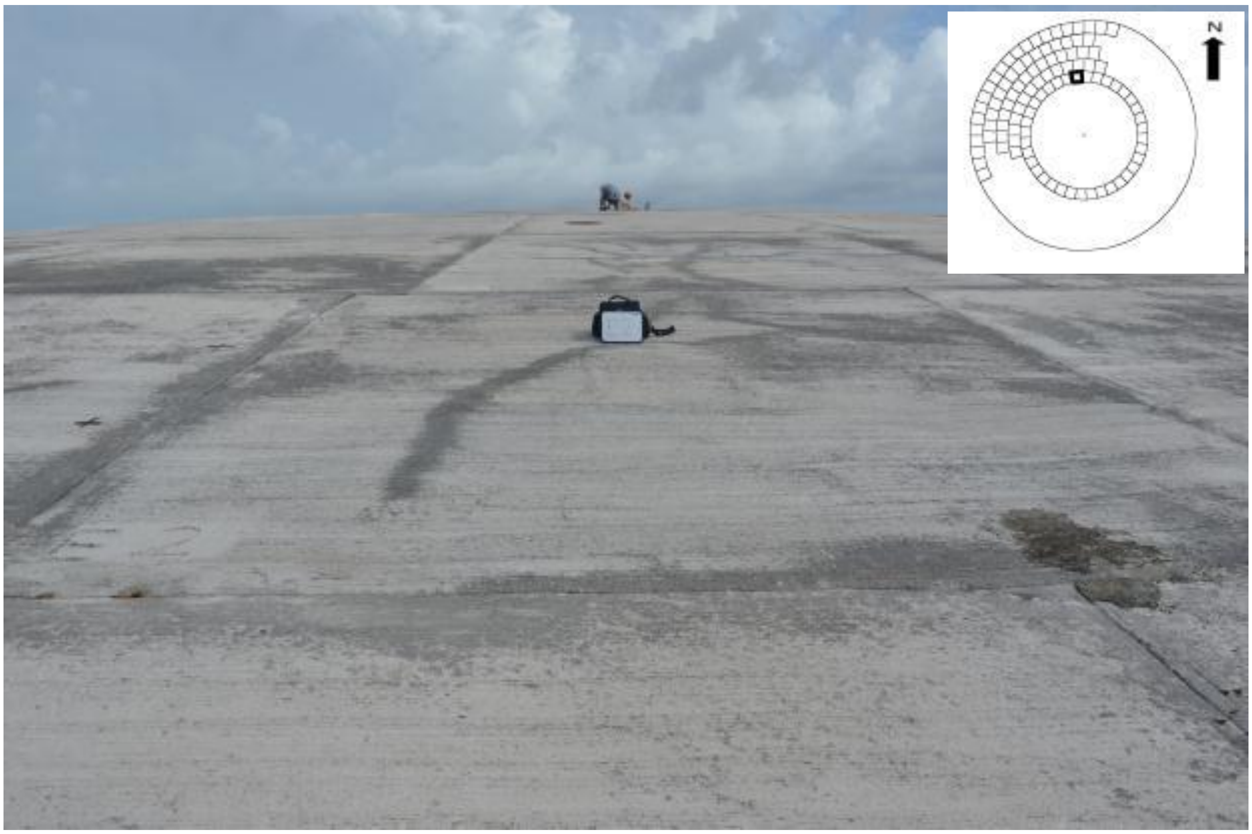
No significant or obvious interior cracks extending across the top of the panel. Some minor spalling/cracking of concrete observed in the upper left-hand corner of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel E2

Description

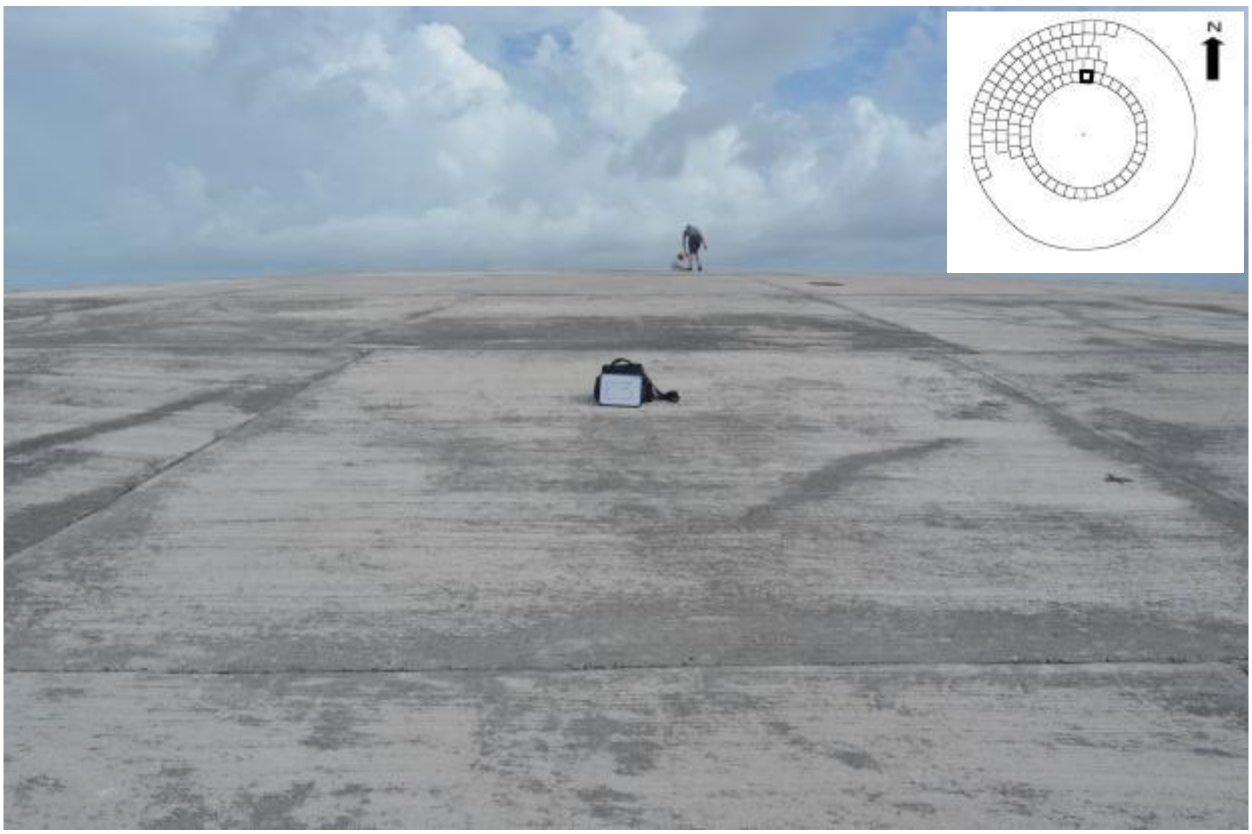
No significant or obvious interior cracks extending across the top of the panel. Some minor spalling/cracking of concrete observed along the lower side of the right seam. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel E3

Description

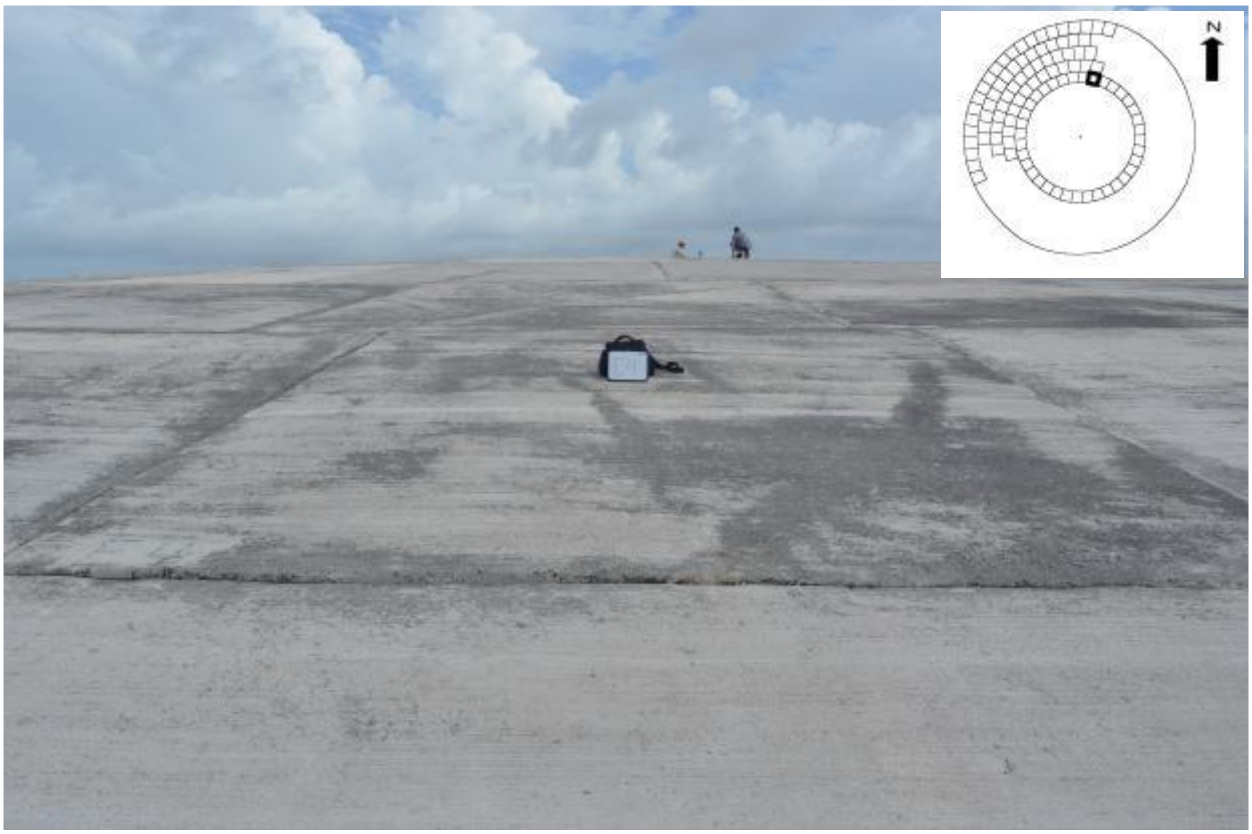
No significant or obvious interior cracks extending across the top of the panel. Some minor spalling/cracking of concrete observed near the upper right-hand corner of the panel.



CAP SECTION LOCATION: Panel E4

Description

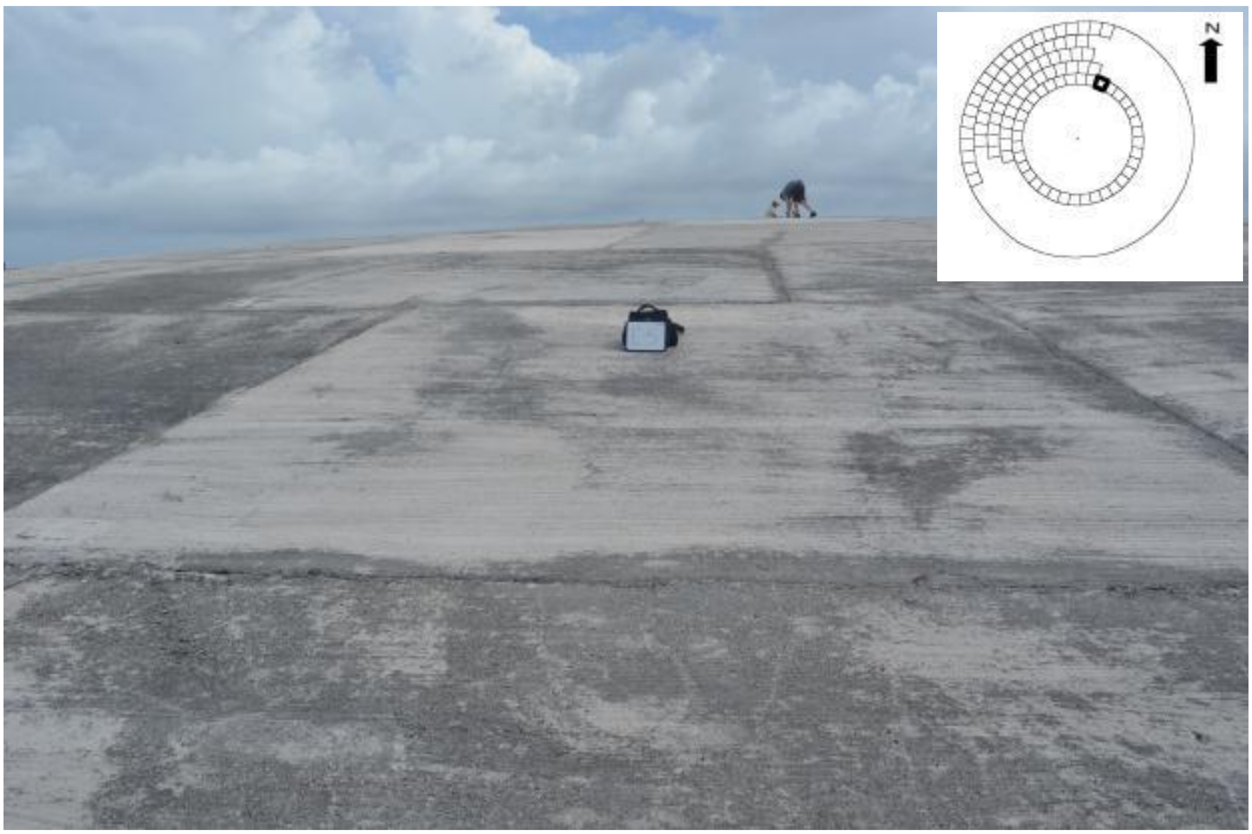
No significant or obvious interior cracks extending across the top of the panel. The bottom right side of the panel has a rough and weathered appearance. Some spalling/cracking of concrete observed in the upper left and right-hand corners of the panel.



CAP SECTION LOCATION: Panel E5

Description

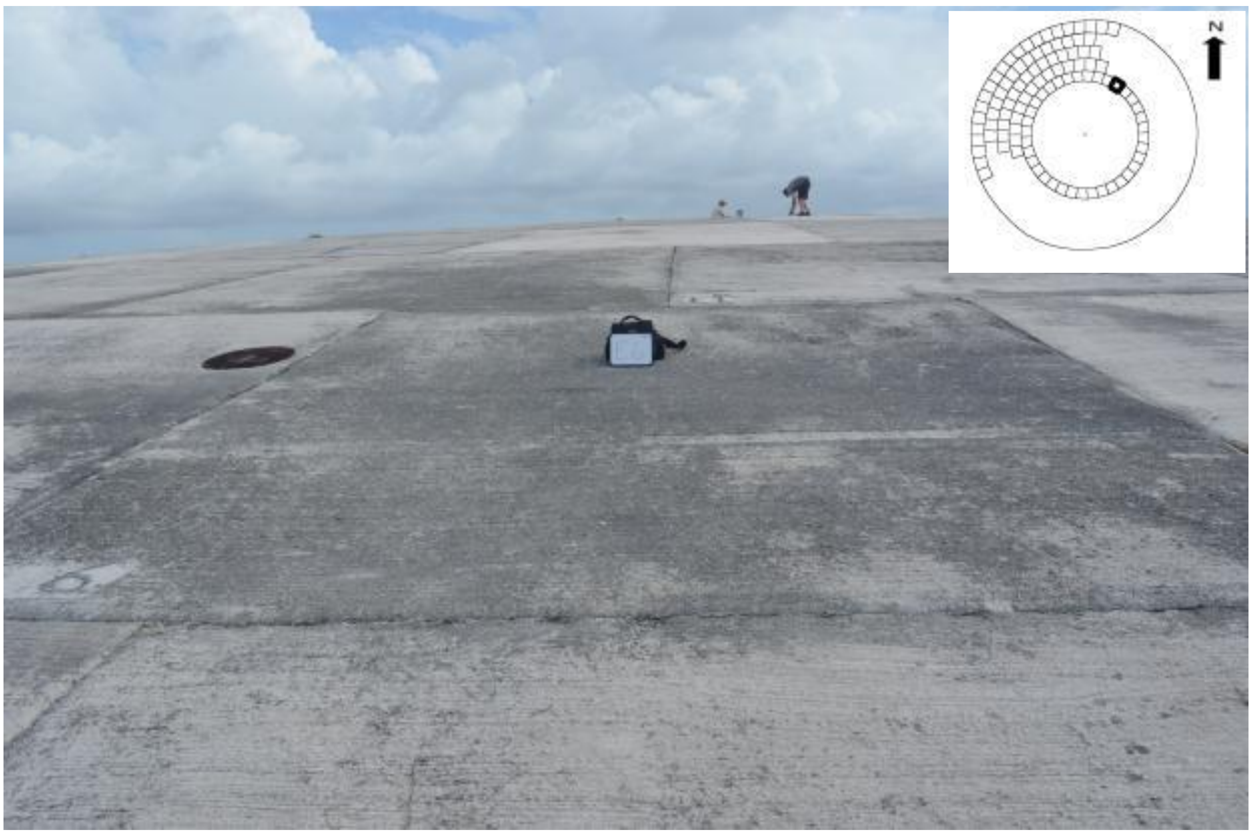
No significant or obvious interior cracks extending across the top of the panel. Some minor spalling/cracking of concrete observed in the lower right corner of the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel E6

Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance.



CAP SECTION LOCATION: Panel E7

Description

No significant or obvious interior cracks extending across the top of the panel. Rooting vegetation (mainly grasses) removed from along the panel seams. Panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel E8

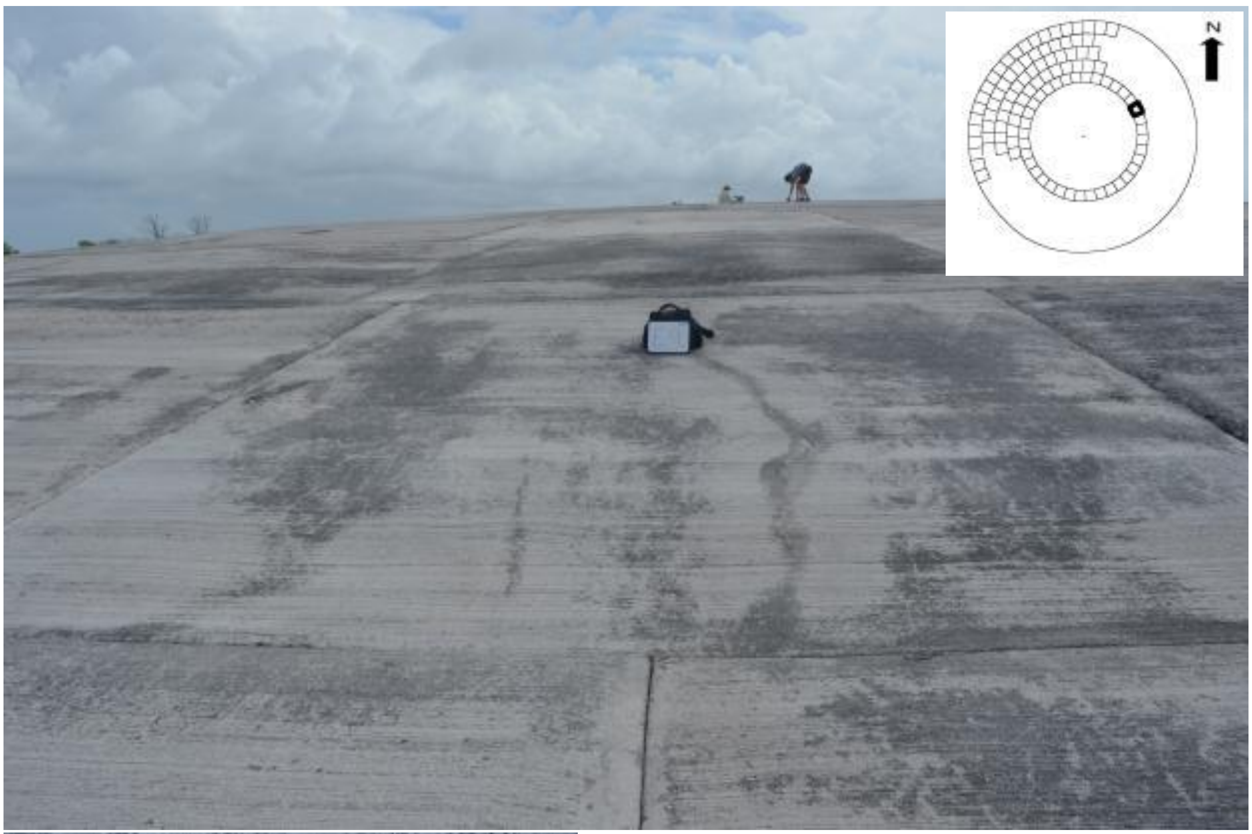
Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance. Some spalling/cracking of concrete observed in the upper left-hand corner of the panel and along the lower left seam

CAP SECTION LOCATION: Panel E9

Description

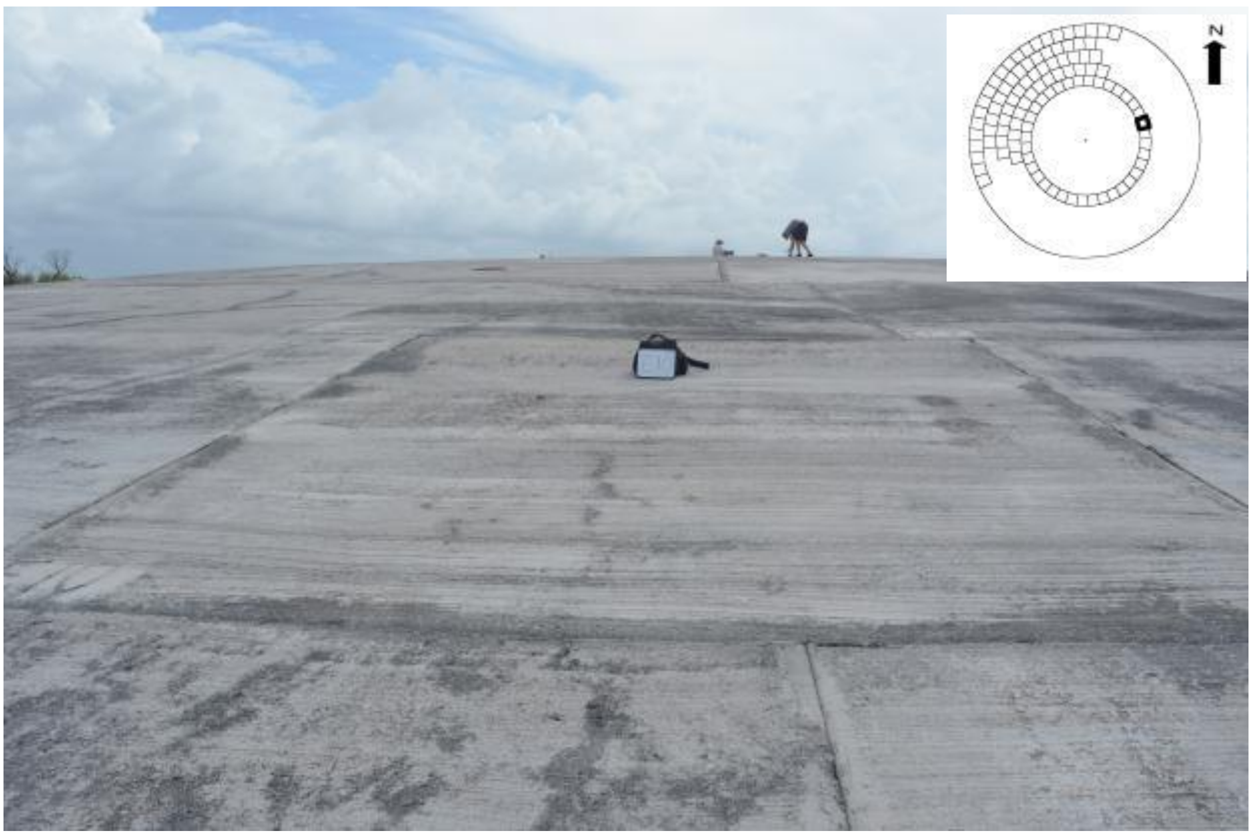
There is a distinguishable crack running up through the middle of the panel. The crack contains chipped “spalled’ edges. Panel recommended for priority repair!



CAP SECTION LOCATION: Panel E10

Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance. Some spalling/cracking of concrete observed in the upper right-hand corner of the panel.



CAP SECTION LOCATION: Panel E11

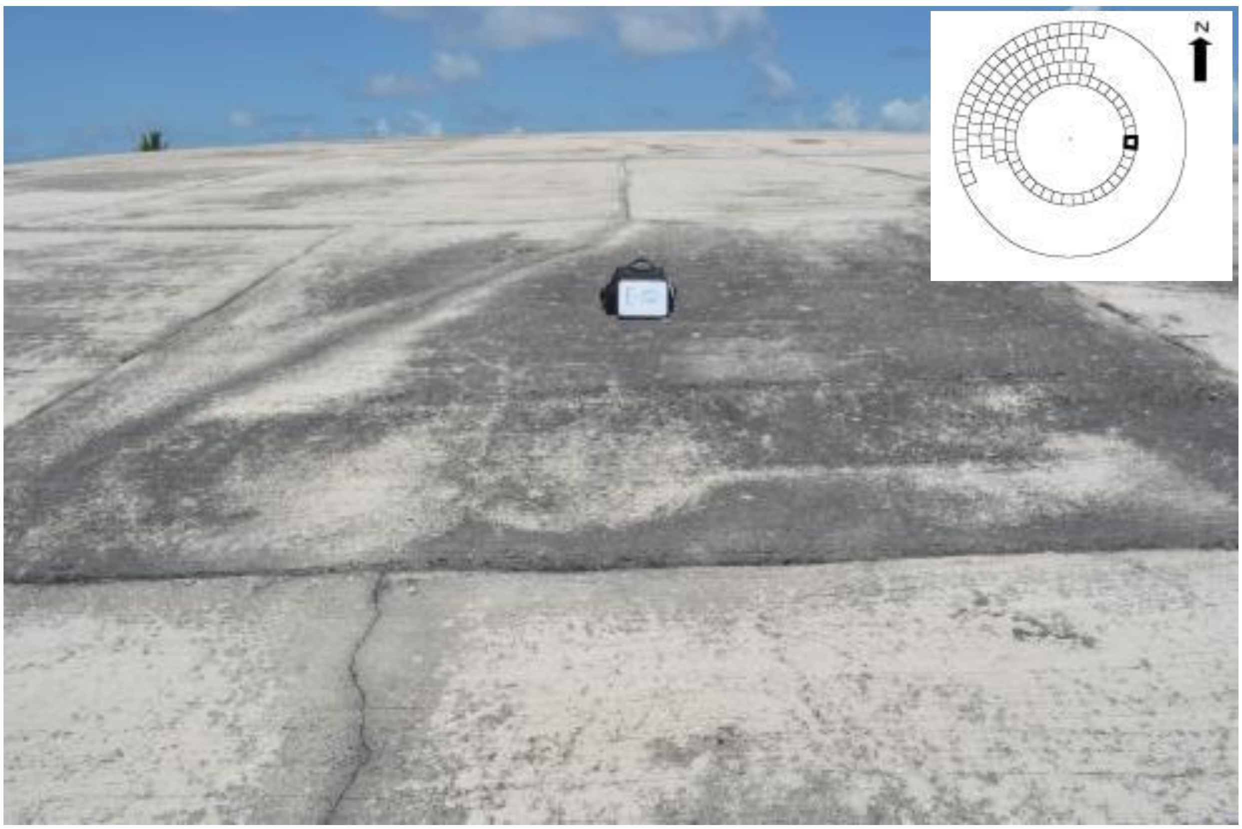
Description

Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. Surface crack observed traversing up through the middle of the panel splitting off to the left-hand seam and extending to the upper right-hand side of the panel.

CAP SECTION LOCATION: Panel E12

Description

Panel has a rough and weathered appearance. Significant spalling/cracking of concrete observed in the upper left corner. The panel also contains a distinguishable crack extending up from the bottom left-side of the panel and intersecting the upper seam at a position adjacent to the corner F9/F10 on the ring row above. Panel recommended for priority repair.



CAP SECTION LOCATION: Panel E13

Description

No significant or obvious interior cracks extending across the top of the panel. Some minor spalling/cracking of concrete observed in the lower left-hand corner of the panel. Panel contains a capped concrete bore-hole (CD-4) from the 1980 NAS investigation.

CAP SECTION LOCATION: Panel E14

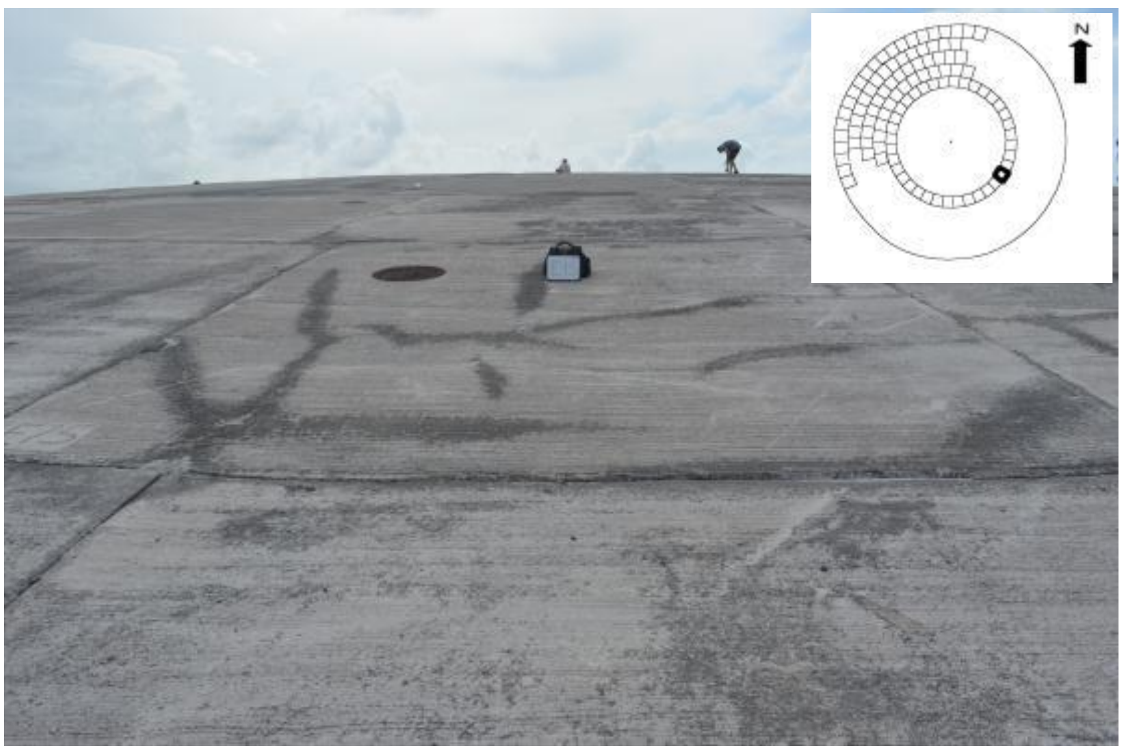
Description

Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. Numerous cracks appearing in a crisscross pattern extending both up and down, and across the panel (following the shaded lines in the photo – see below).

CAP SECTION LOCATION: Panel E15

Description

Significant spalling of concrete observed along the lower seam of the panel, especially adjacent to the intersection corner D18/D19 on the ring row below. A distinguishable crack extends up and across the panel from the same position and intersects the left seam about 2 meters up from the base of the panel. A similar crack occurs across the right-hand corner with other minor cracks forming in a crisscross pattern across the middle of the panel. The panel contains a vertical elevation benchmark. It is recommended that the panel receive priority for repair!



CAP SECTION LOCATION: Panel E16

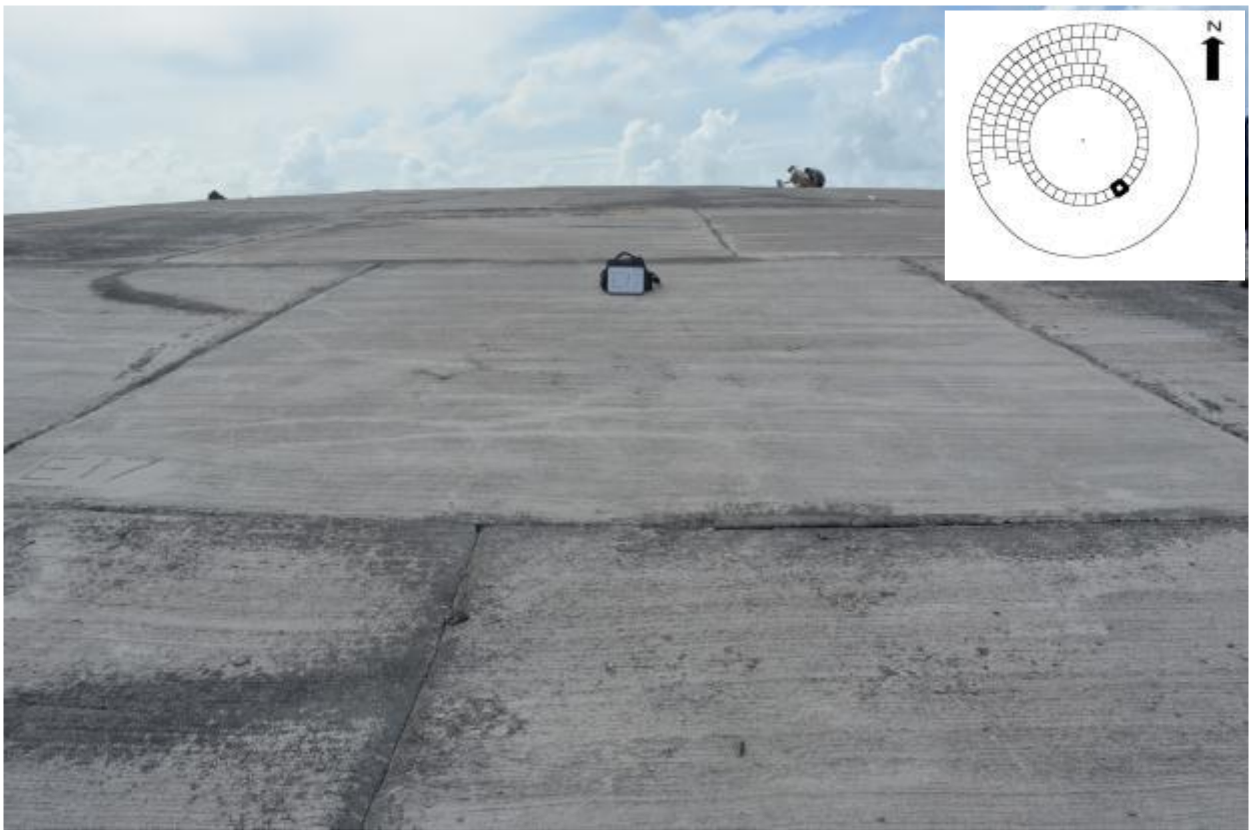
Description

No significant or obvious interior cracks extending across the top of the panel. The upper portion of the panel has a rough and weathered appearance.

CAP SECTION LOCATION: Panel E17

Description

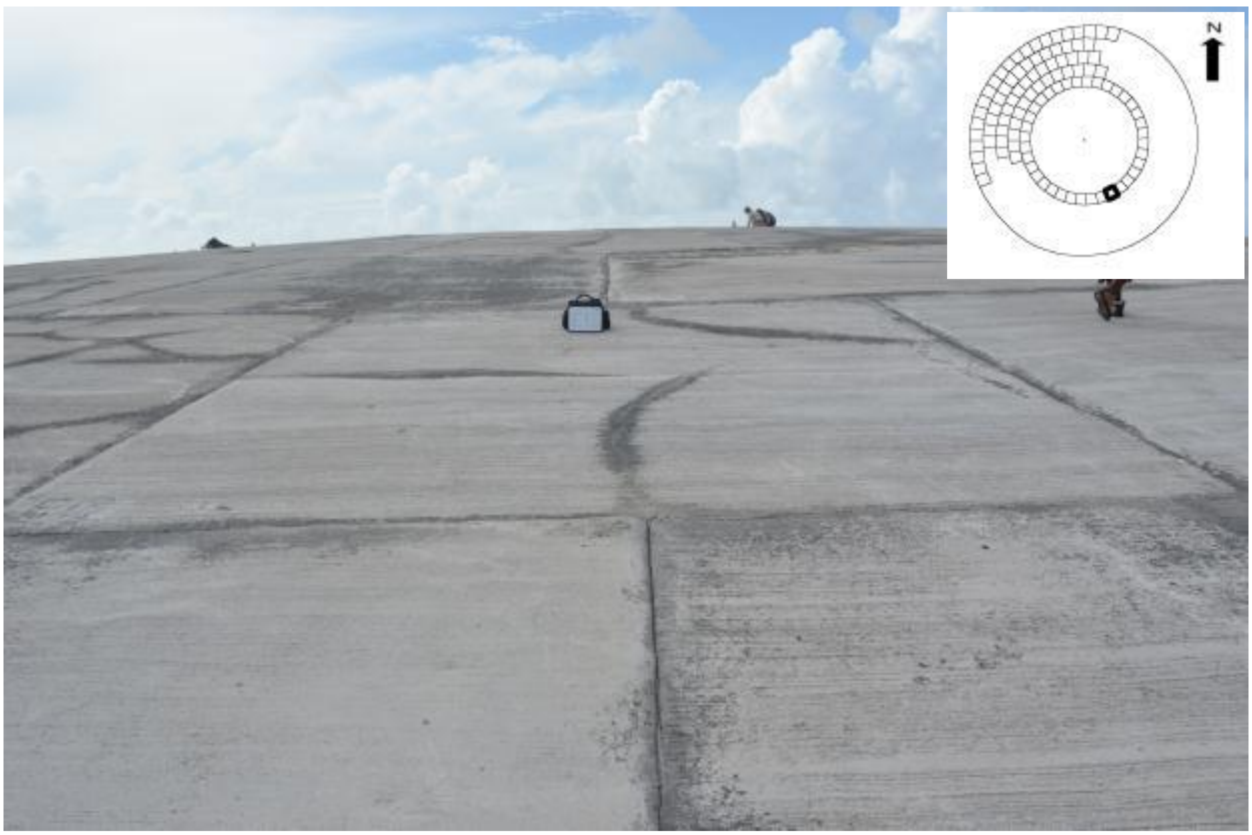
Significant spalling/chipping of concrete observed along the lower seam of the panel. The panel contains no other significant or obvious spalls or cracks.



CAP SECTION LOCATION: Panel E18

Description

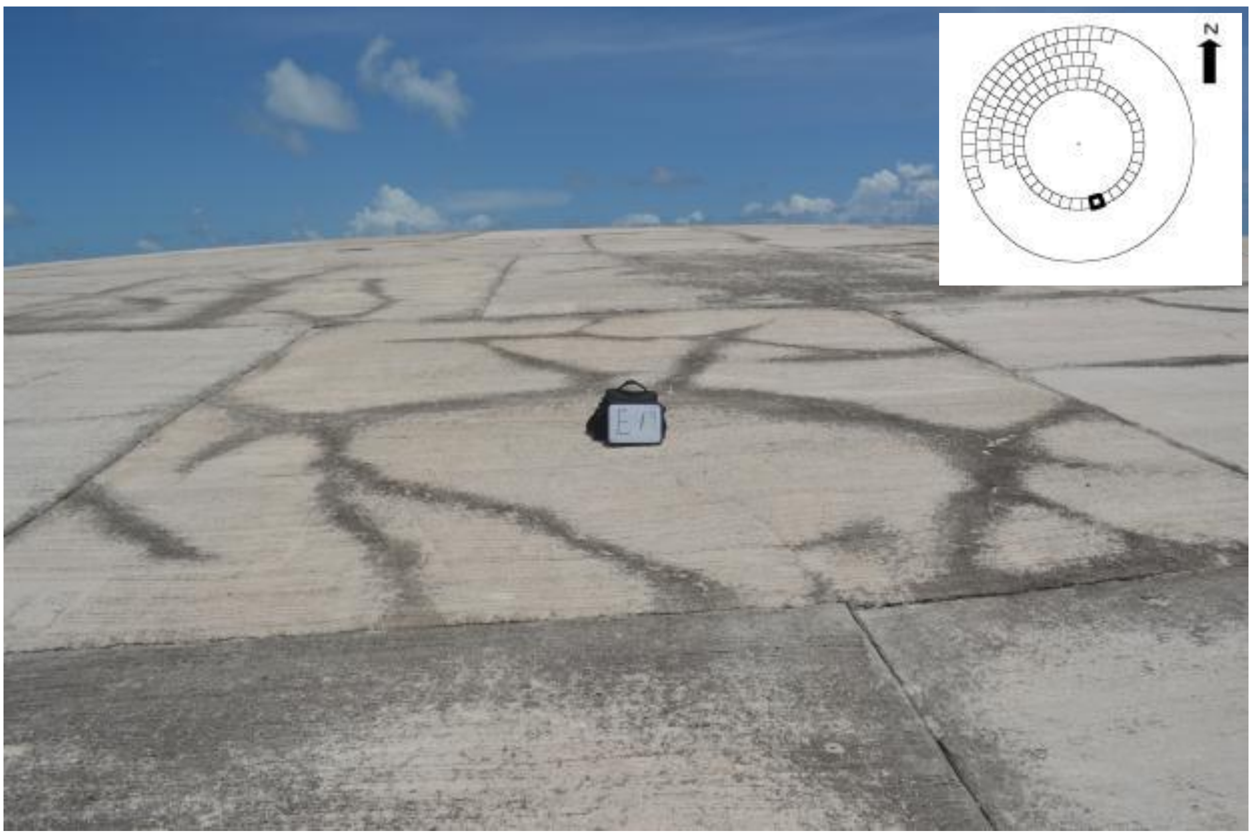
Some spalling/cracking of concrete observed in the upper right-hand corner of the panel. A surface crack extends up from the base of the panel adjacent to the intersecting corner D23/D24 of the ring row below. A minor crack was observed running parallel with the left seam at a mid-point up the panel.



CAP SECTION LOCATION: Panel E19

Description

Numerous surface cracks appearing in crisscross pattern up and down as well as across the panel. Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. Crack lines can be visualized by following the pattern of discoloration in the concrete (refer to photo below)..



CAP SECTION LOCATION: Panel E20

Description

No significant or obvious interior cracks extending across the top of the panel.

CAP SECTION LOCATION: Panel E21

Description

Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. No obvious interior cracks or spalls extending across the top of the panel with exception of a small voided piece of concrete in the upper right corner (app. 4 x 2-2.5 centimeters in area).

CAP SECTION LOCATION: Panel E22

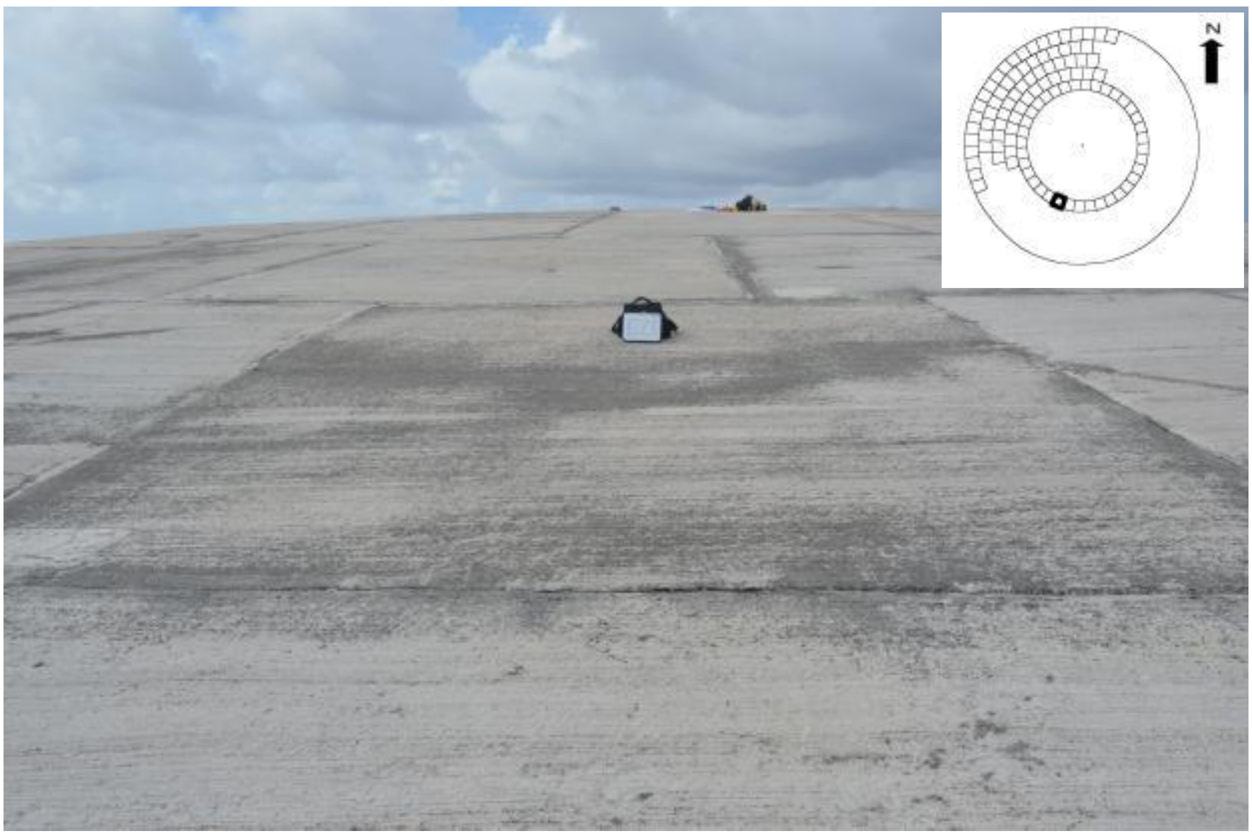
Description

Some spalling/cracking of concrete observed in the upper right-hand corner of the panel. Numerous cracks were observed extending up and down as well as across the panel (as observed by the shaded areas in the photo below). Panel recommended for priority repair!

CAP SECTION LOCATION: Panel E23

Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance. Concrete in the upper left-hand corner of the panel appears to be more highly weathered than other areas.



CAP SECTION LOCATION: Panel E24

Description

Some spalling/cracking of concrete observed along the lower left and right seams of the panel. Surface cracks observed crisscrossing up and down as well as across the panel. Most cracks have chipped "spalled" edges and can be visualized by following the pattern of discoloration across the panel (refer to photo below). Panel is recommended for priority repair.

CAP SECTION LOCATION: Panel E25

Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance. Panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel E26

Description

Some spalling/cracking of concrete observed on the left-hand side of the lower seam. Surface cracks observed in the lower left-hand corner of the panel. Additional minor cracks have formed up and across the panel, the most significant of which intersects the left side seam about 2 meters from the top of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel E27

Description

Panel has a rough and weathered appearance. The main observable feature is a surface crack running left to right at a mid-point up the panel. Cracks have chipped “spalled” edges. Other very minor cracks observed forming a crisscrossing pattern around the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel E28

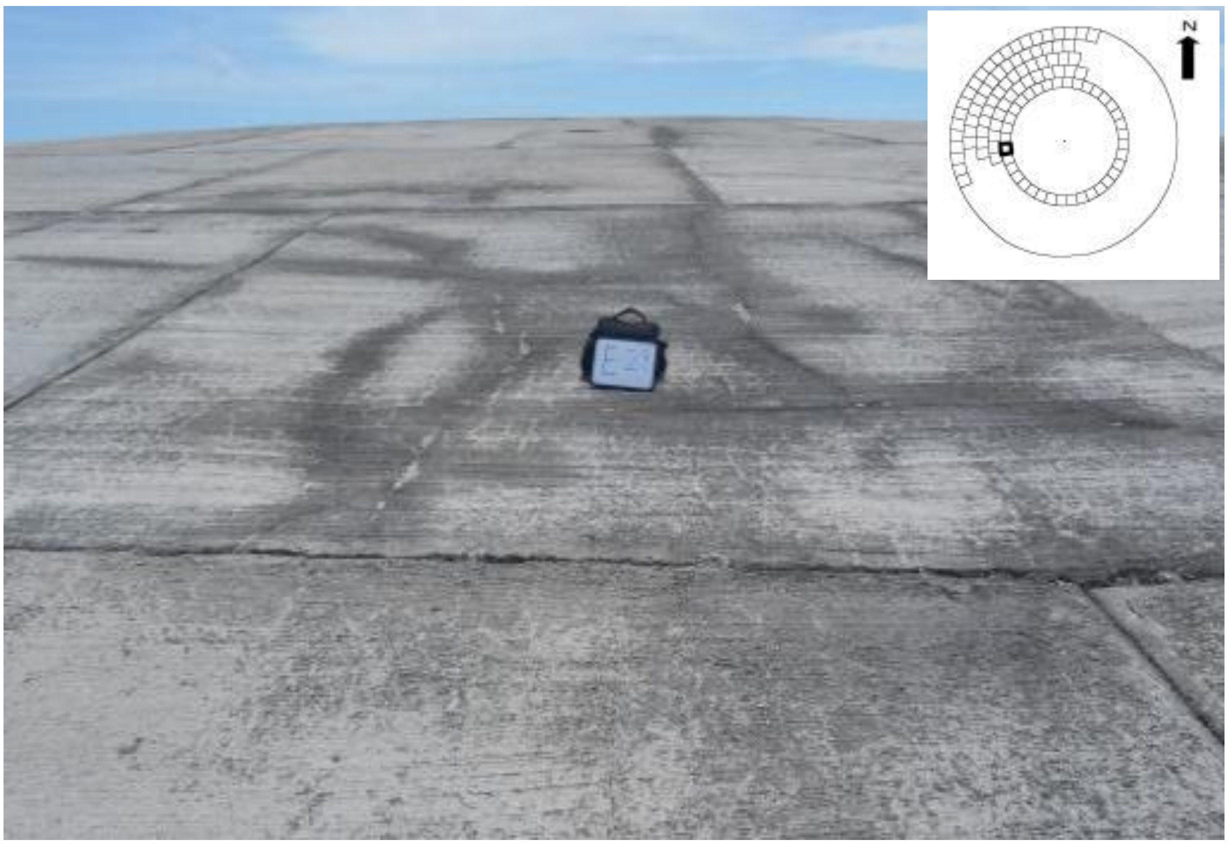
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel E29

Description

There are numerous cracks with chipped “spalled” edges crisscrossing up and across the panel. Some spalling/cracking of concrete observed in the right-hand corner of the panel.



CAP SECTION LOCATION: Panel E30

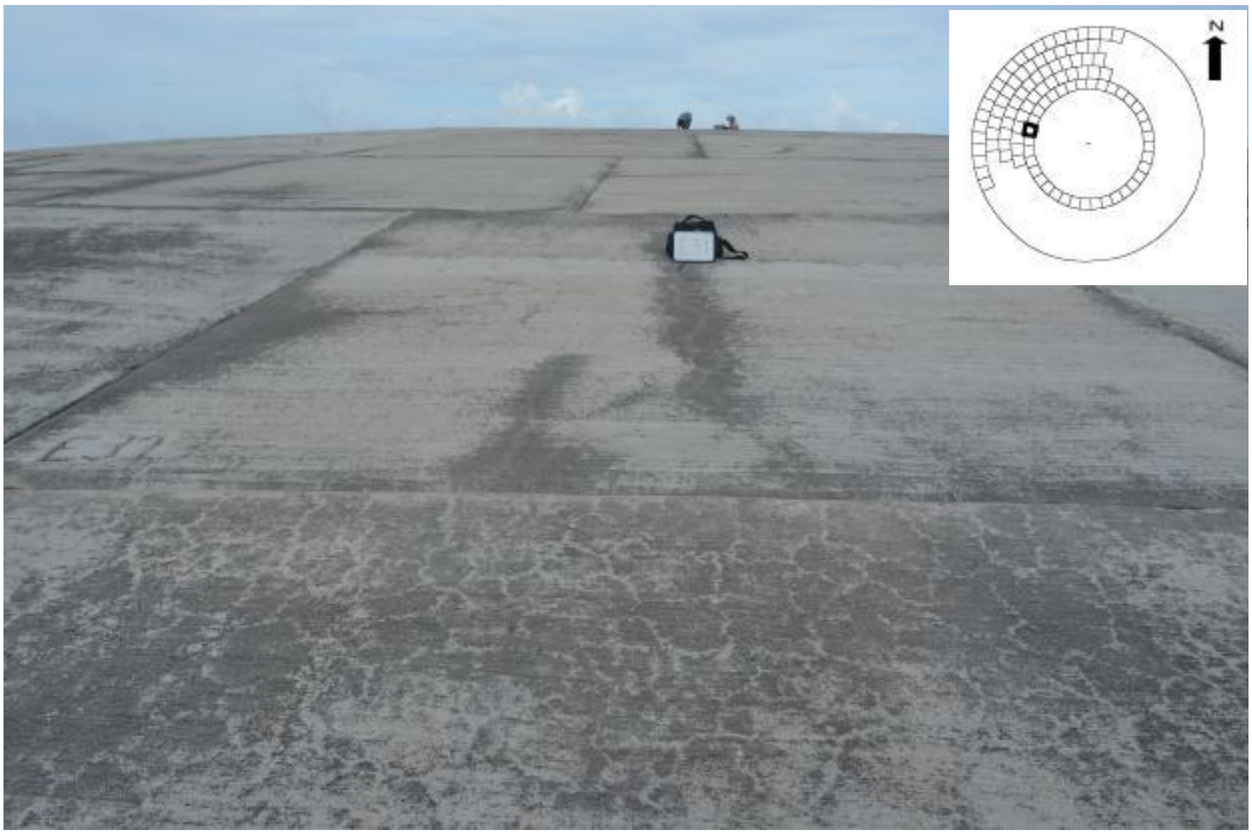
Description

No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel E31

Description

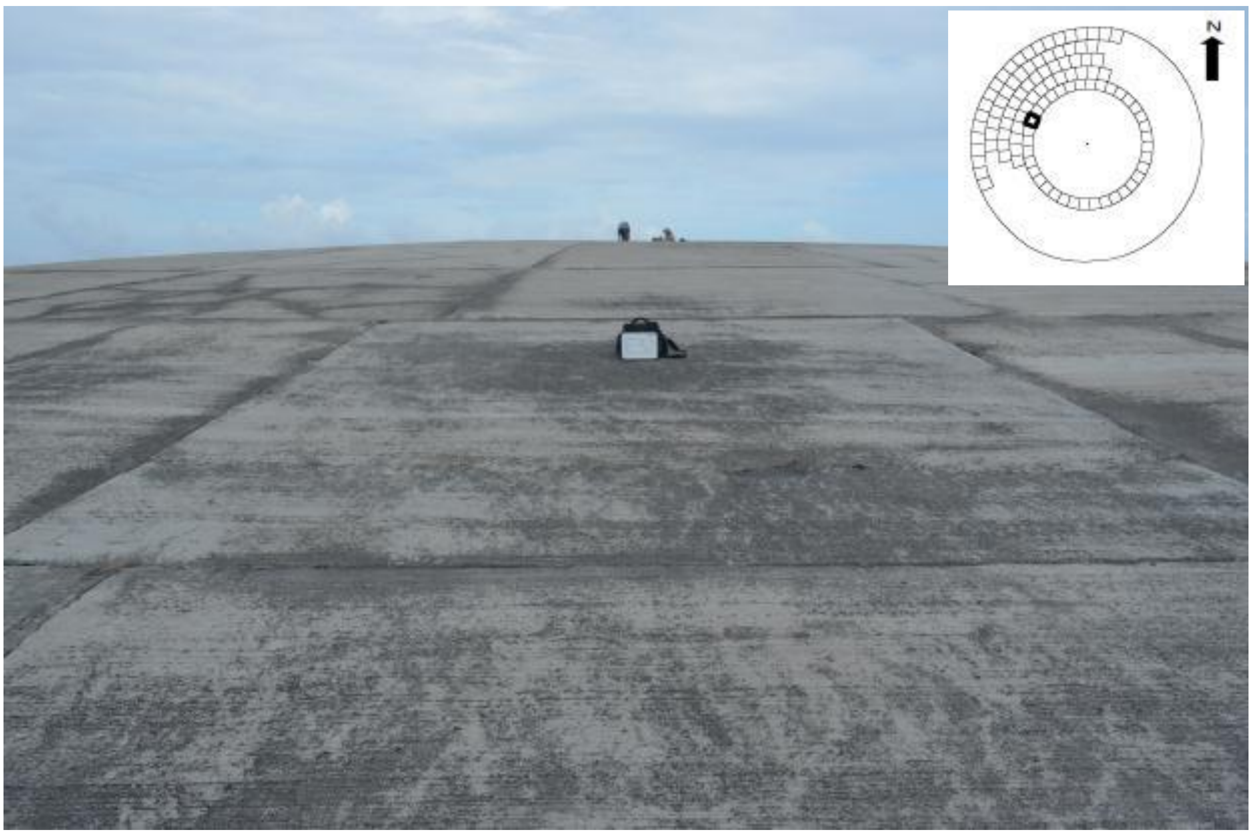
No significant or obvious interior cracks extending across the top of the panel. The upper portion of the panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel E32

Description

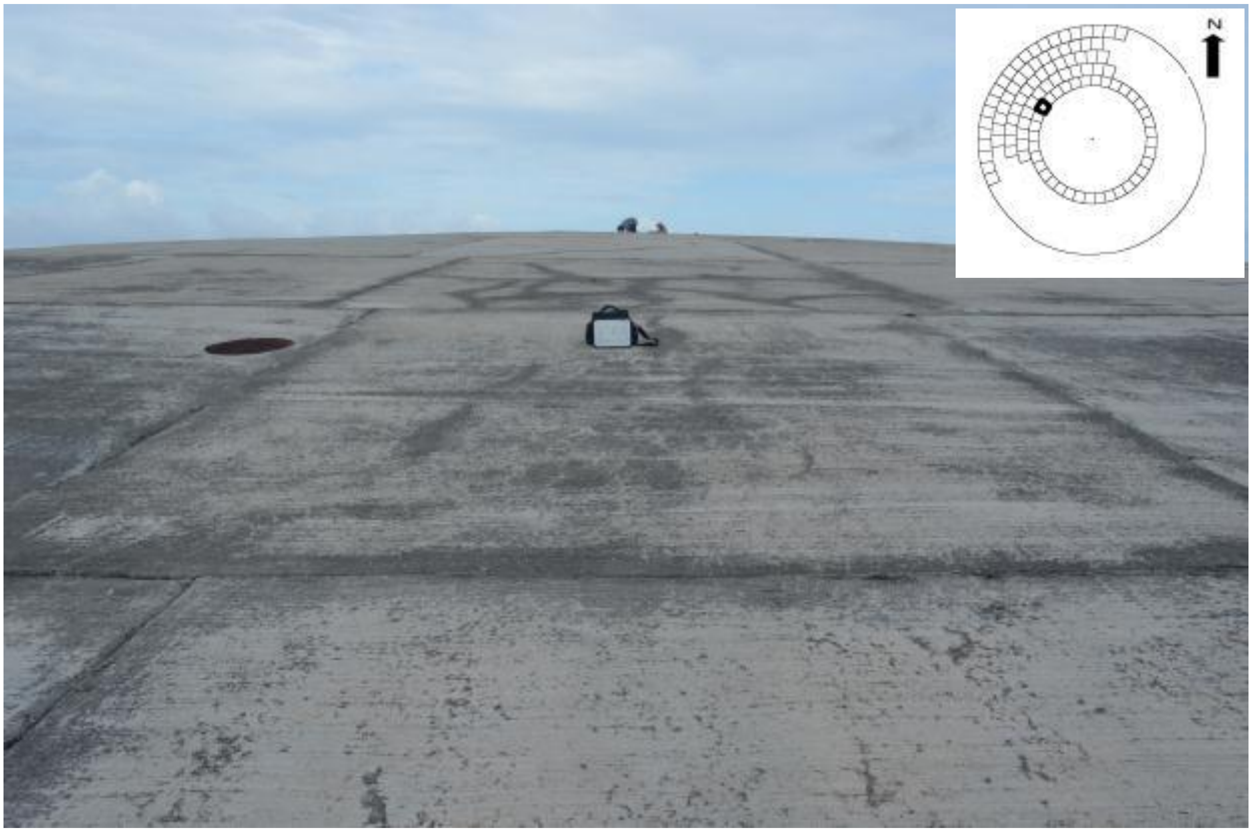
No significant or obvious interior cracks extending across the top of the panel. Panel has a rough and weathered appearance. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel E33

Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance.



CAP SECTION LOCATION: Panel E34

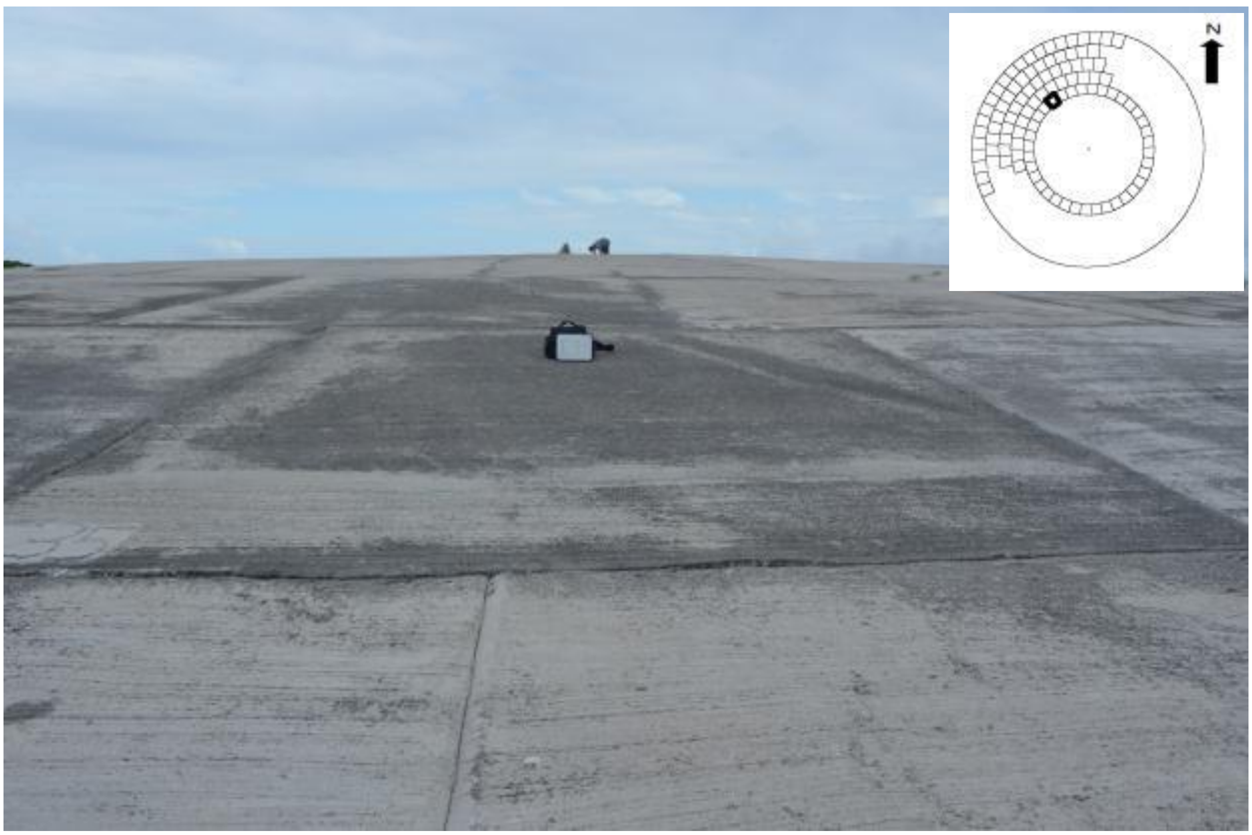
Description

No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance. Panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel E35

Description

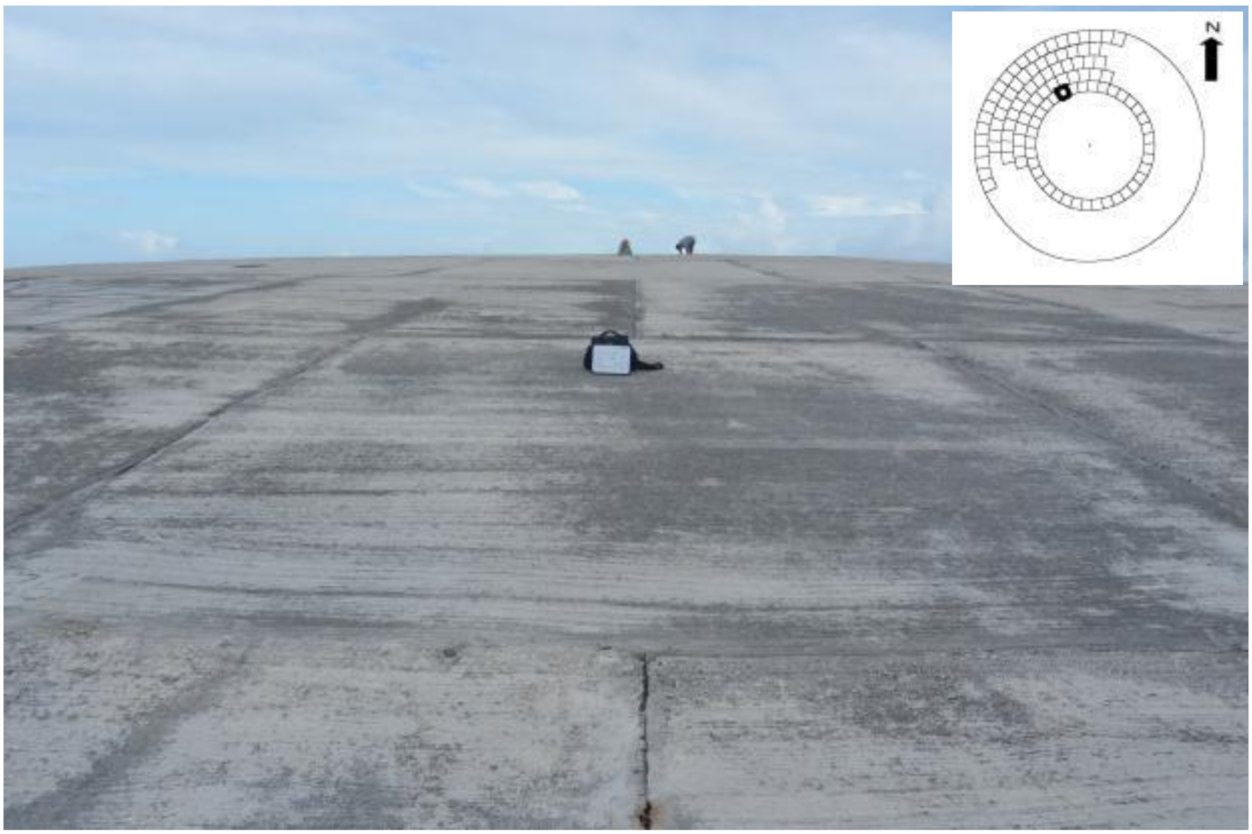
No significant or obvious interior cracks extending across the top of the panel. The panel has a rough and weathered appearance.



CAP SECTION LOCATION: Panel E36

Description

The panel has a rough and weathered appearance. Some spalling/cracking of concrete observed along the upper and lower right seams, and in the upper right-hand corner, of the panel.



CAP SECTION LOCATION: Panel F1

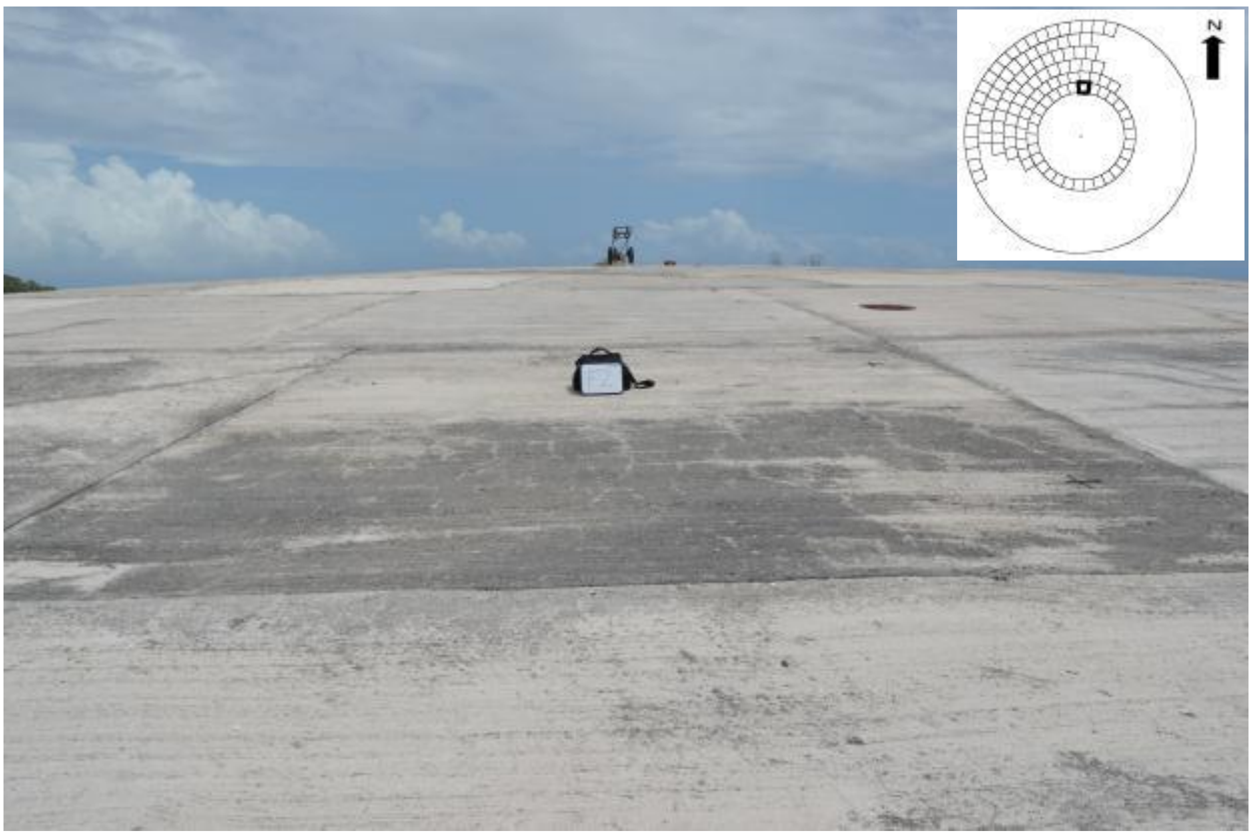
Description

Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. Minor surface cracks extending up from the bottom seam in a crisscross pattern. and intersecting with the upper and left seams of the panel.

CAP SECTION LOCATION: Panel F2

Description

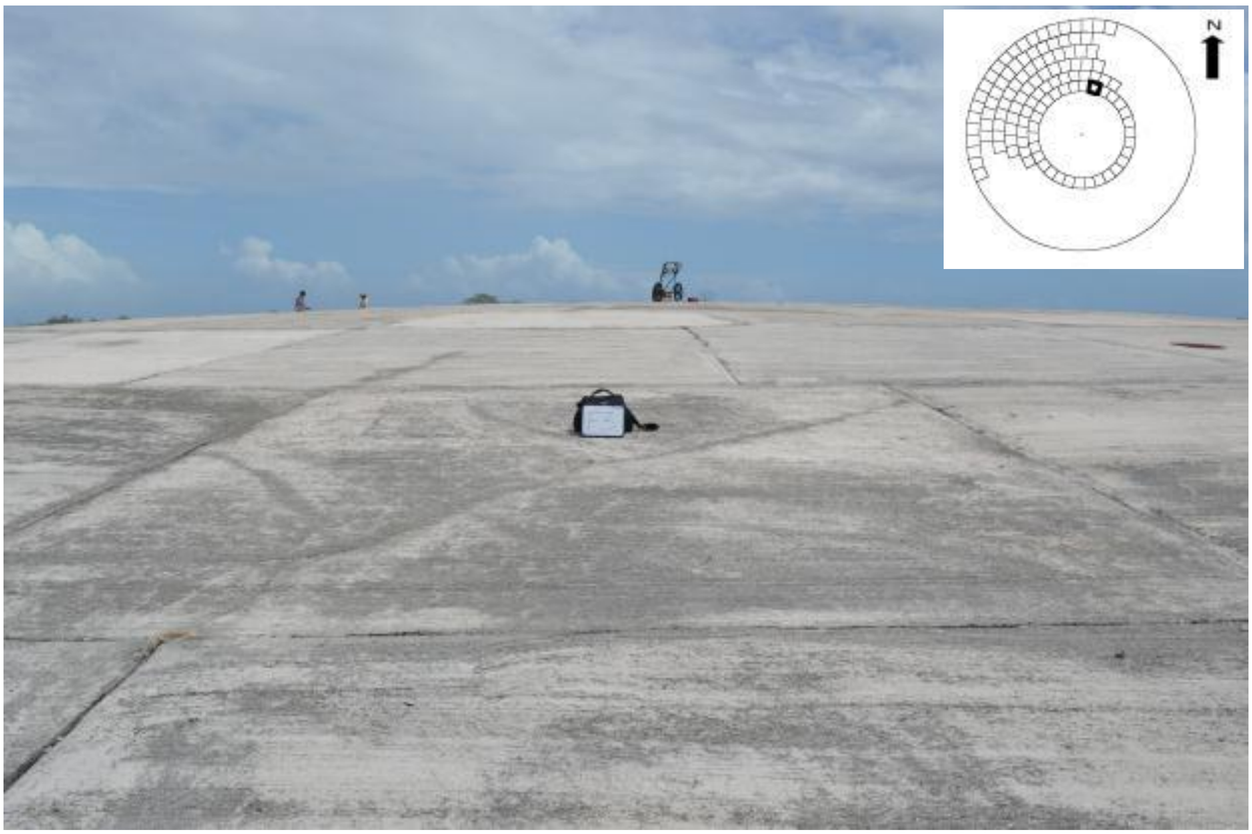
The panel contains patches of discolored concrete. Some spalling/cracking of concrete observed in the upper left and right-hand corners of the panel. No significant or obvious interior cracks or spalls extending across the top of the panel with exception of numerous very minor cracks. Also, there is a small void in the concrete appearing near the upper left-hand corner (app. 4 centimeters deep, and 1 x 3 centimeters in area).



CAP SECTION LOCATION: Panel F3

Description

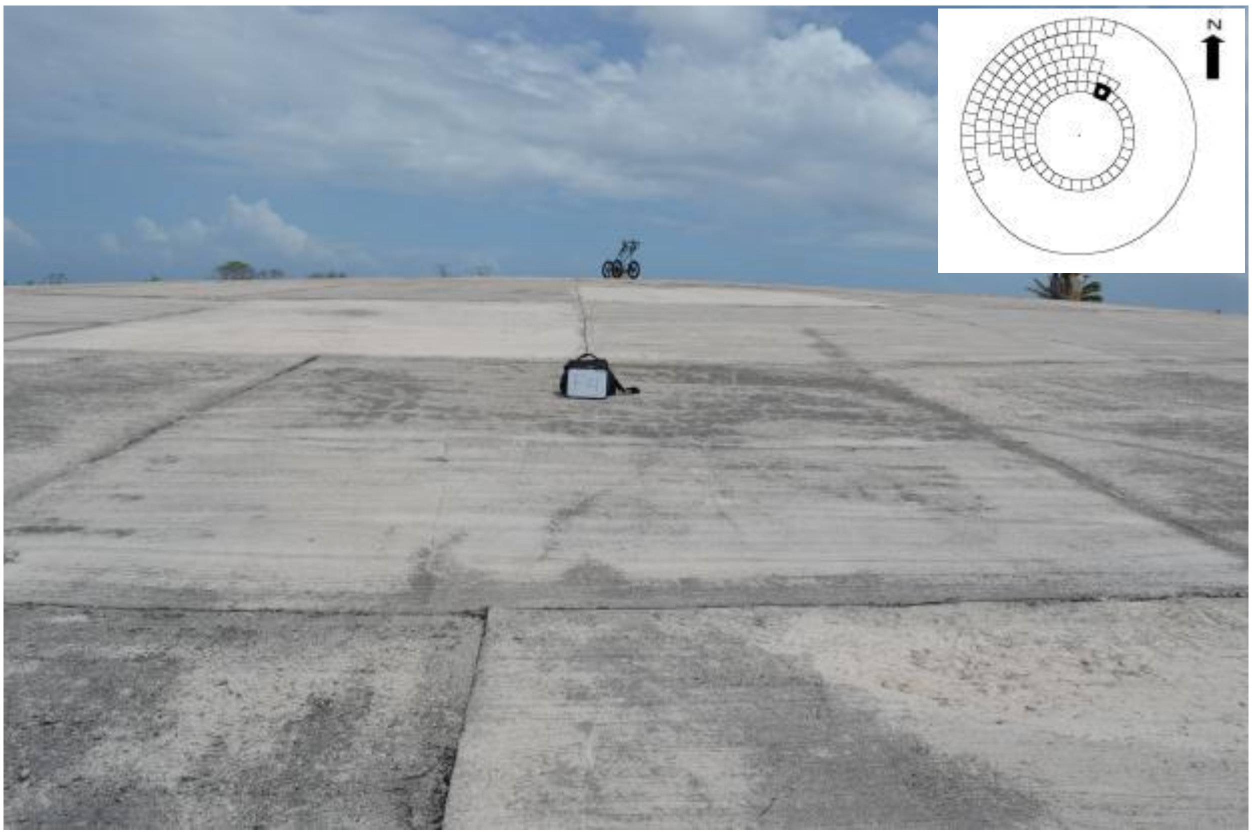
A crack readily identified traversing up from the bottom seam from a point adjacent to the corner intersection of the E4/E5 panels on the ring row below, and traveling across the middle of the panel towards the upper right-hand corner with a fork out to the left-hand side of the panel.



CAP SECTION LOCATION: Panel F4

Description

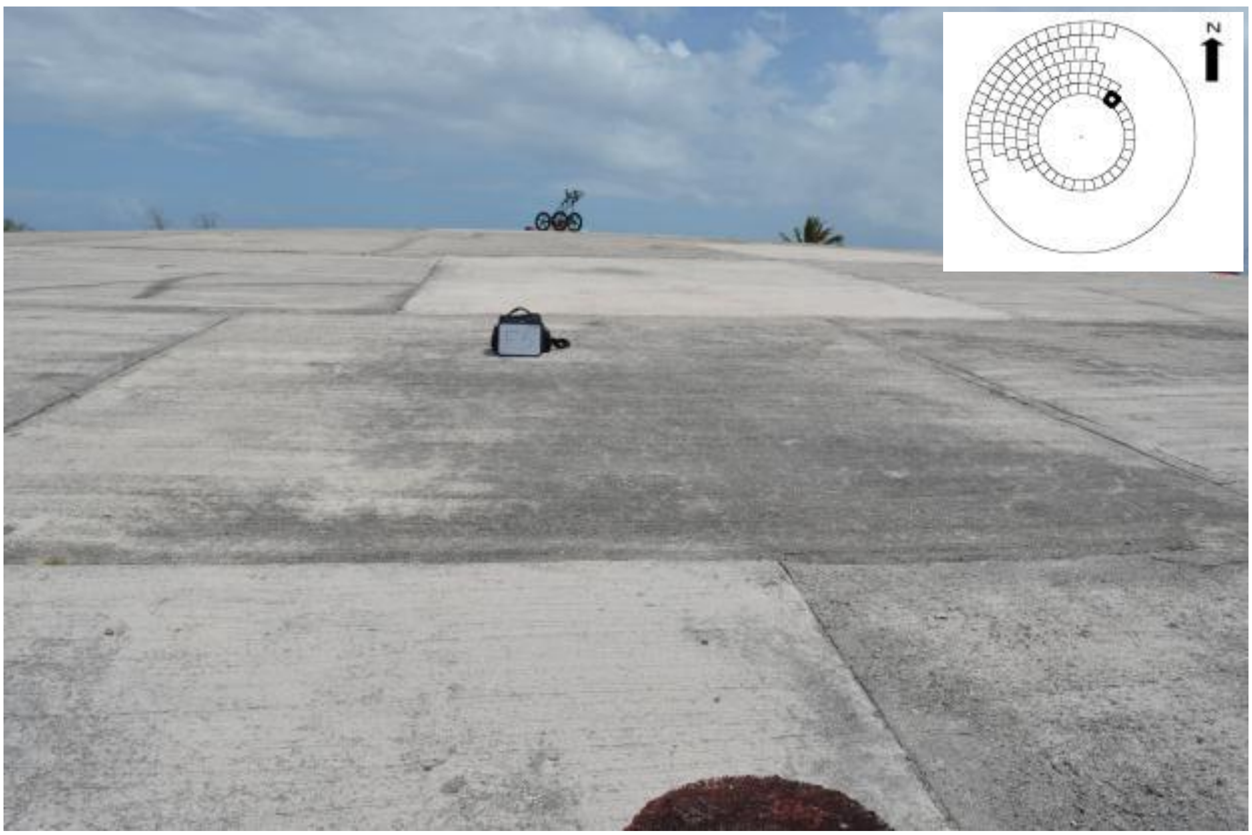
A surface crack is visible traversing up from the bottom seam from a point adjacent to the corner intersection of the E5/E6 panels on the ring rows below. Some spalling/chipping of concrete observed in the upper left-hand corner of the panel.



CAP SECTION LOCATION: Panel F5

Description

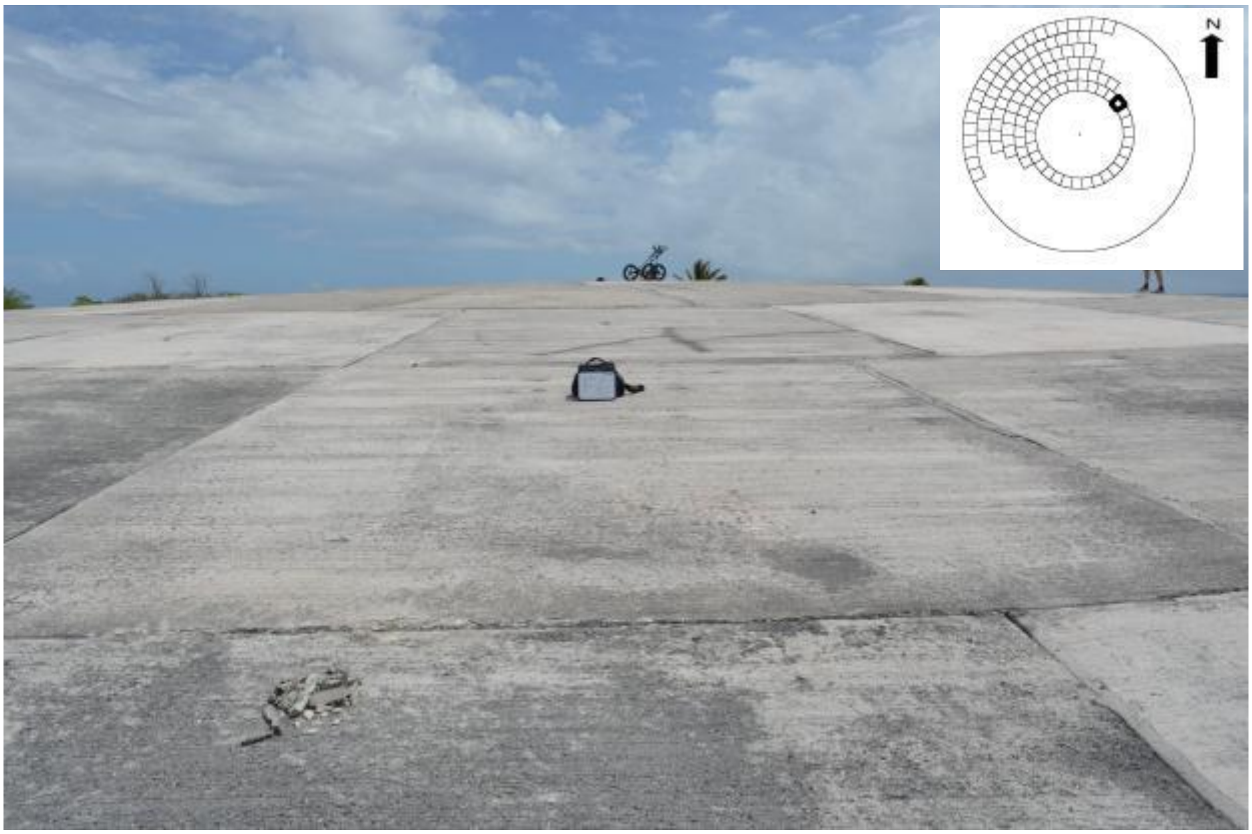
No significant or obvious interior cracks or spall elements identified but there does appear to be a little more separation along the seams with the adjoining panels, especially in the upper right corner of the panel. In this instance, the edge of the panel is overhanging the bottom of panel G5 on the ring row above.



CAP SECTION LOCATION: Panel F6

Description

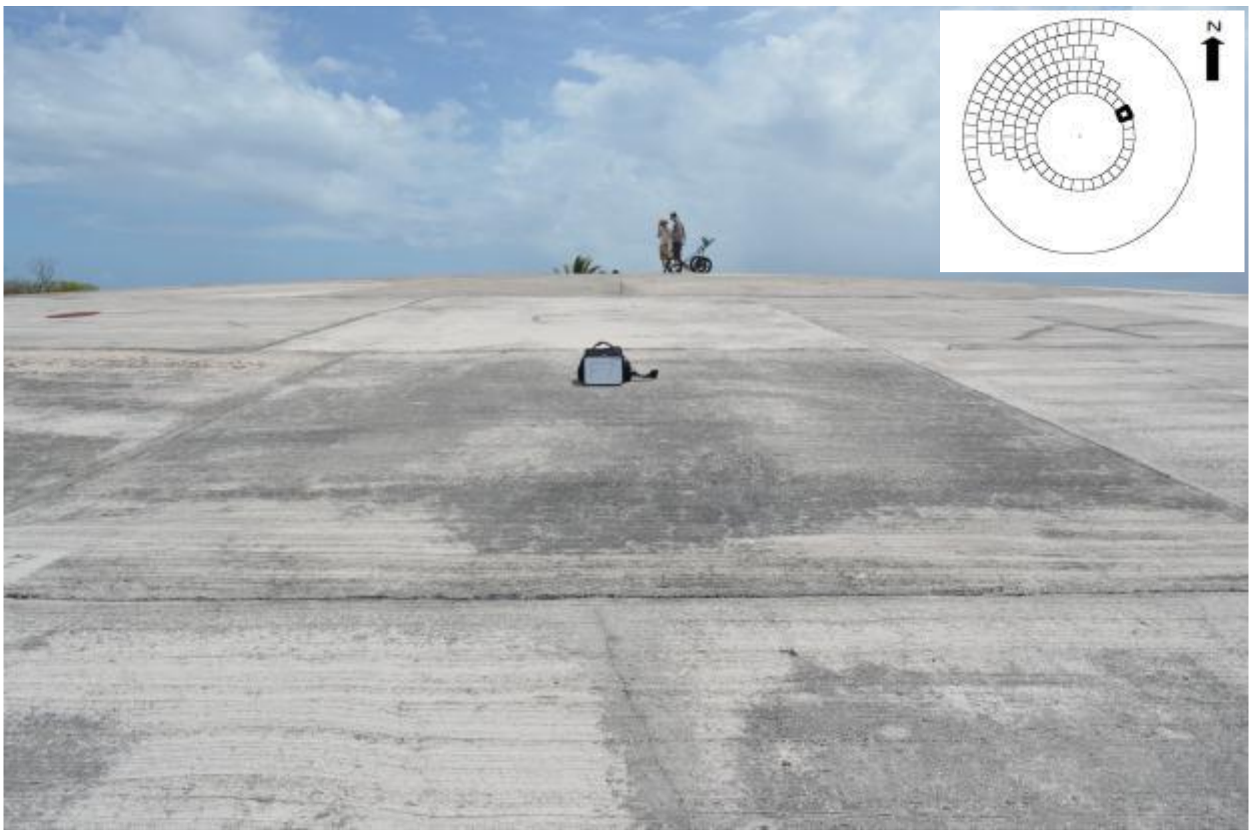
No significant or obvious interior cracks or spall elements identified. Some spalling/cracking of concrete in the upper left-hand corner and along the bottom seam of the panel.



CAP SECTION LOCATION: Panel F7

Description

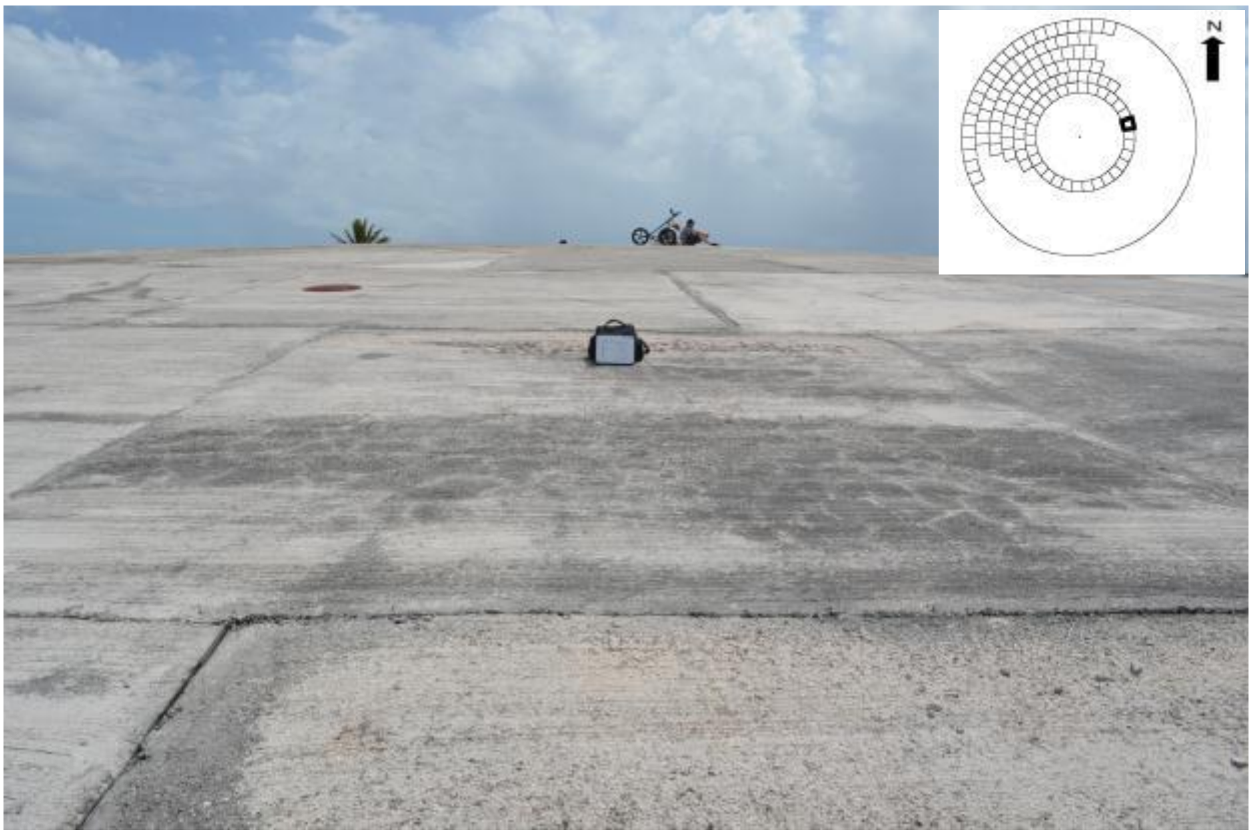
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel F8

Description

The panel has a slightly weathered appearance across the bottom of the segment. No significant or obvious interior cracks or spall elements identified. Some minor spalling/cracking of concrete along the upper seam of the panel.



CAP SECTION LOCATION: Panel F9

Description

Some spalling/cracking of concrete observed in the upper and lower left-hand corners of the panel. A surface crack is visible traversing up from the bottom seam from a point adjacent to the corner intersection of the E11/E12 panels on the ring row below, and traveling up the panel towards the right before branching into a fork extending upwards and out to the right side of the panel.

CAP SECTION LOCATION: Panel F10

Description

No significant or obvious interior cracks or spall elements identified. Some spalling/cracking of concrete observed along the bottom seam of the panel.

CAP SECTION LOCATION: Panel F11

Description

The panel contains patches of discolored concrete. No significant or obvious interior cracks or spall elements identified. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel F12

Description

The panel contains patches of discolored concrete. There is some spalling/chipping of concrete evident in the bottom left-hand corner of the panel. Also, minor spalling/chipping of concrete observed across the top seam of the panel. Rooting vegetation removed from along the panel seams. Panel contains a filled bore-hole (CD-5) from the 1980 NAS investigation.

CAP SECTION LOCATION: Panel F13

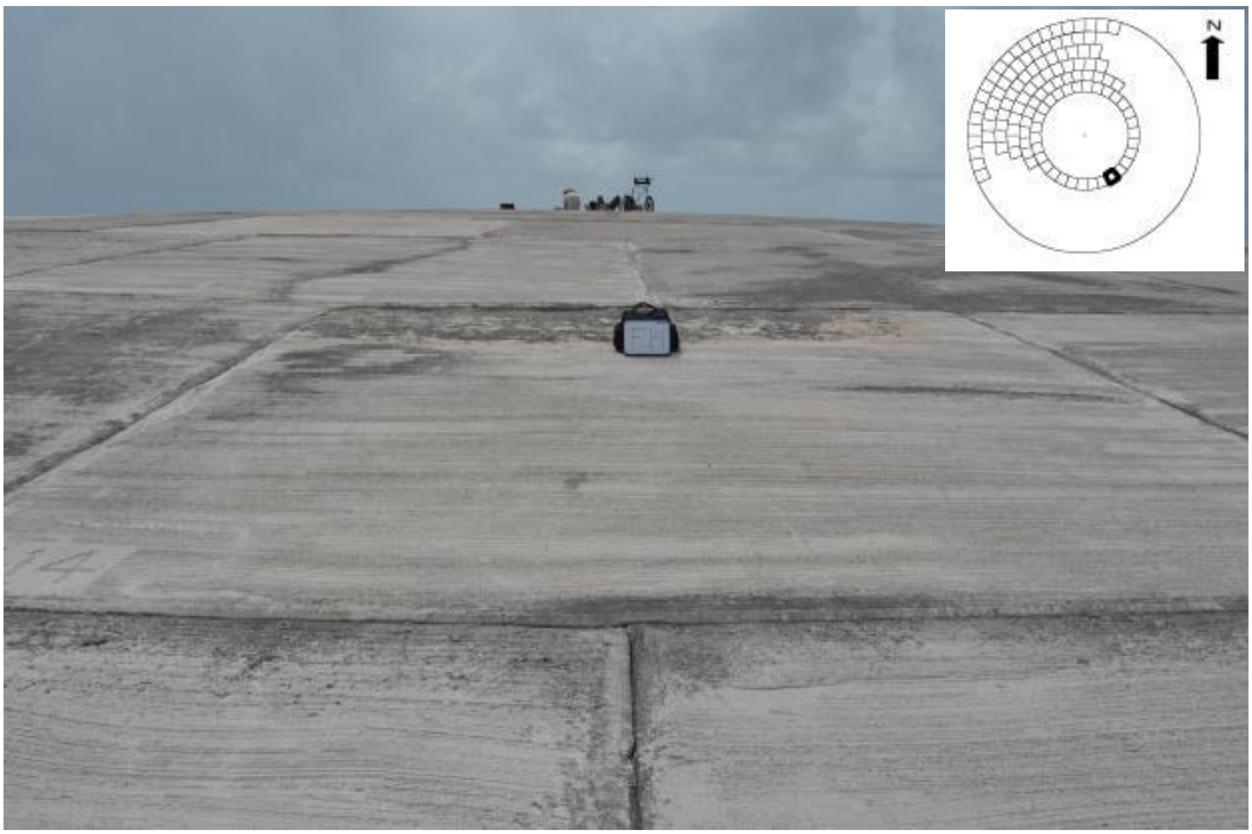
Description

No significant or obvious interior cracks or spall elements identified. Some minor spalling/chipping of concrete in the top and bottom left-hand corners of the panel.

CAP SECTION LOCATION: Panel F14

Description

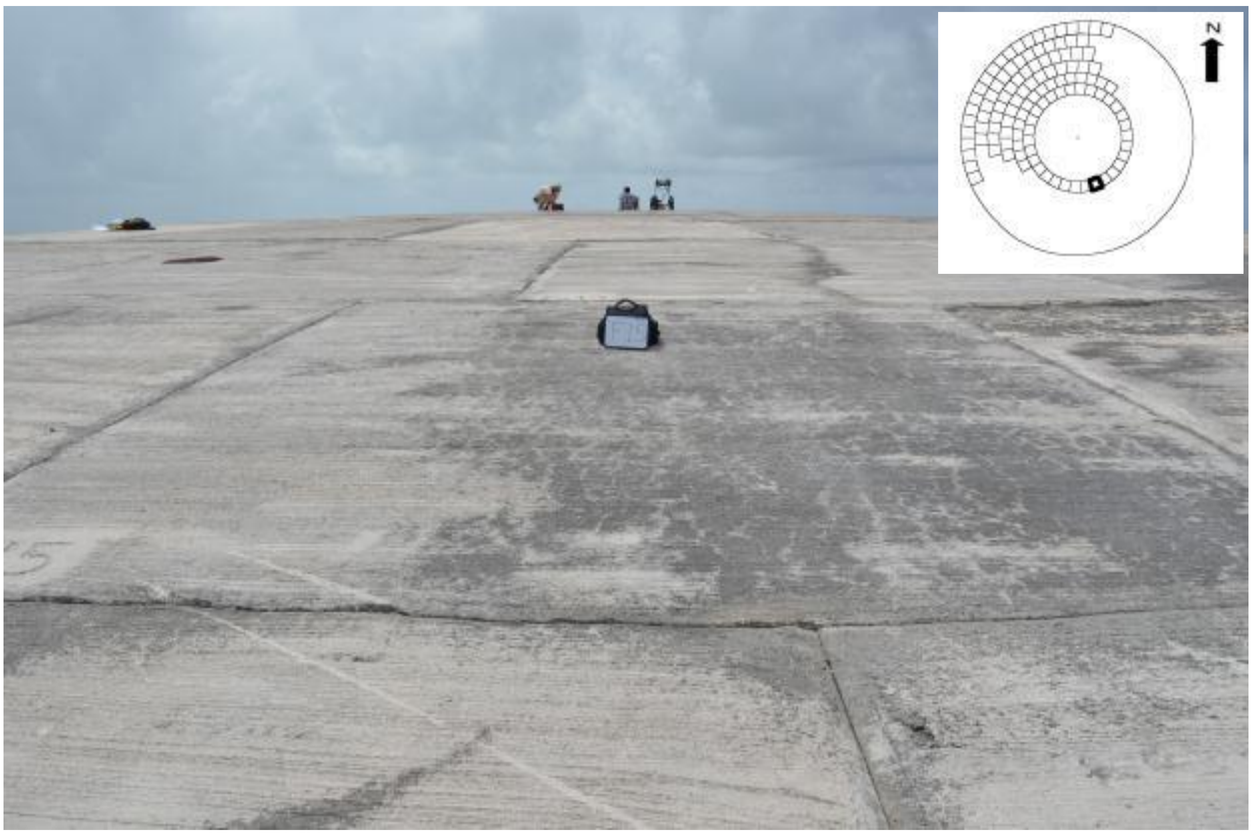
Top portion of the panel has a rough and weathered appearance. No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel F15

Description

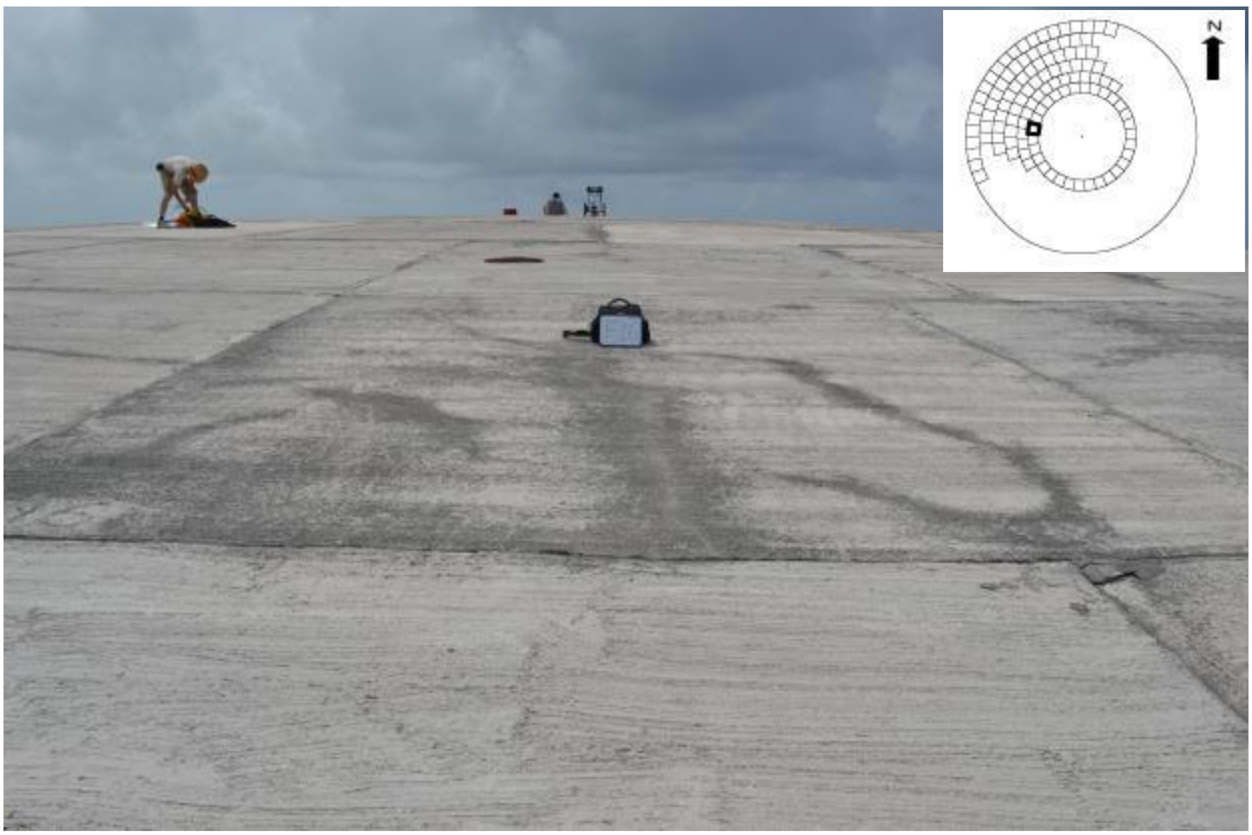
The panel contains patches of discolored concrete. No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel F16

Description

Rooting vegetation removed from along the panel seams. A surface crack with spalled edges is clearly visible traversing up from the bottom seam from a point adjacent to the corner intersection of the E19/E20 panels on the ring rows below. There is a separate crack traversing up through the middle of the panel from a central position along the bottom seam.



CAP SECTION LOCATION: Panel F17

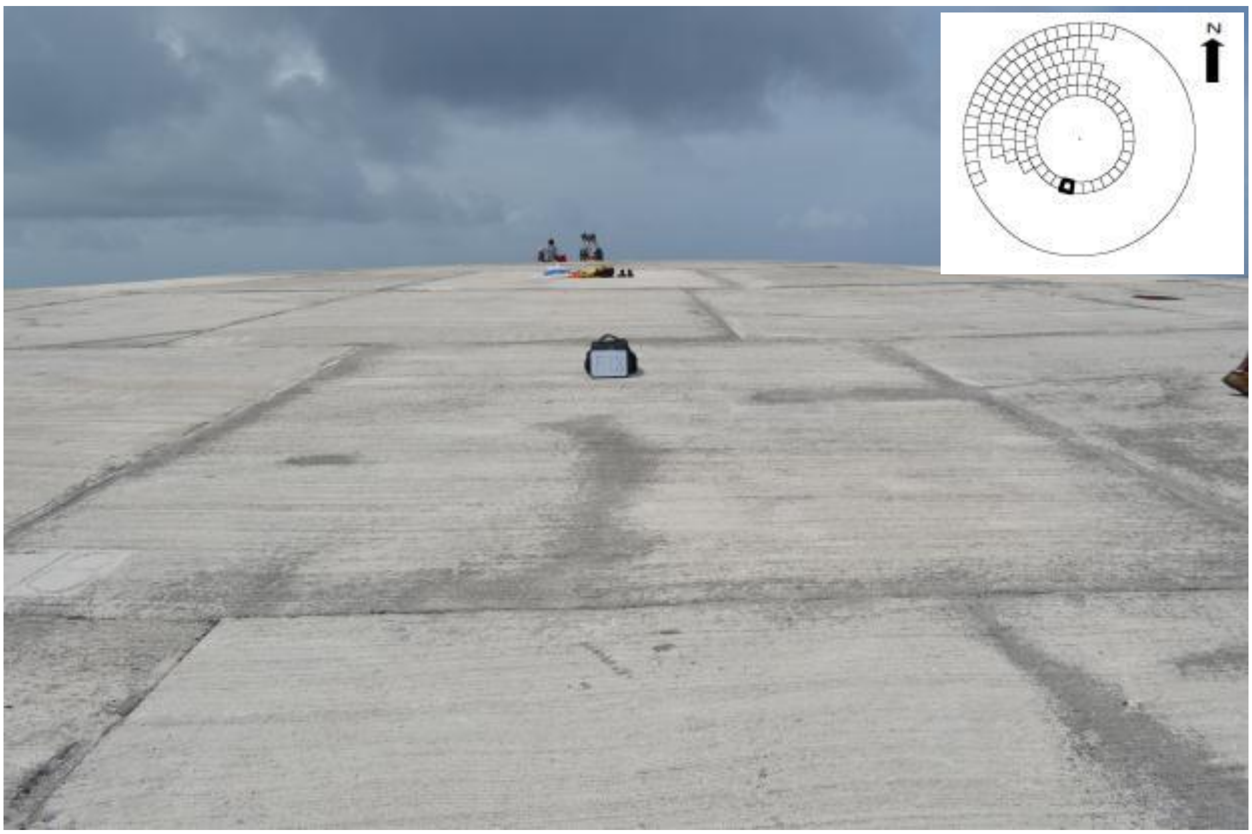
Description

No significant or obvious interior cracks or spall elements identified. Rooting vegetation removed from along the panel seams. Some minor spalling/chipping of concrete in bottom right-hand corner of the panel.

CAP SECTION LOCATION: Panel F18

Description

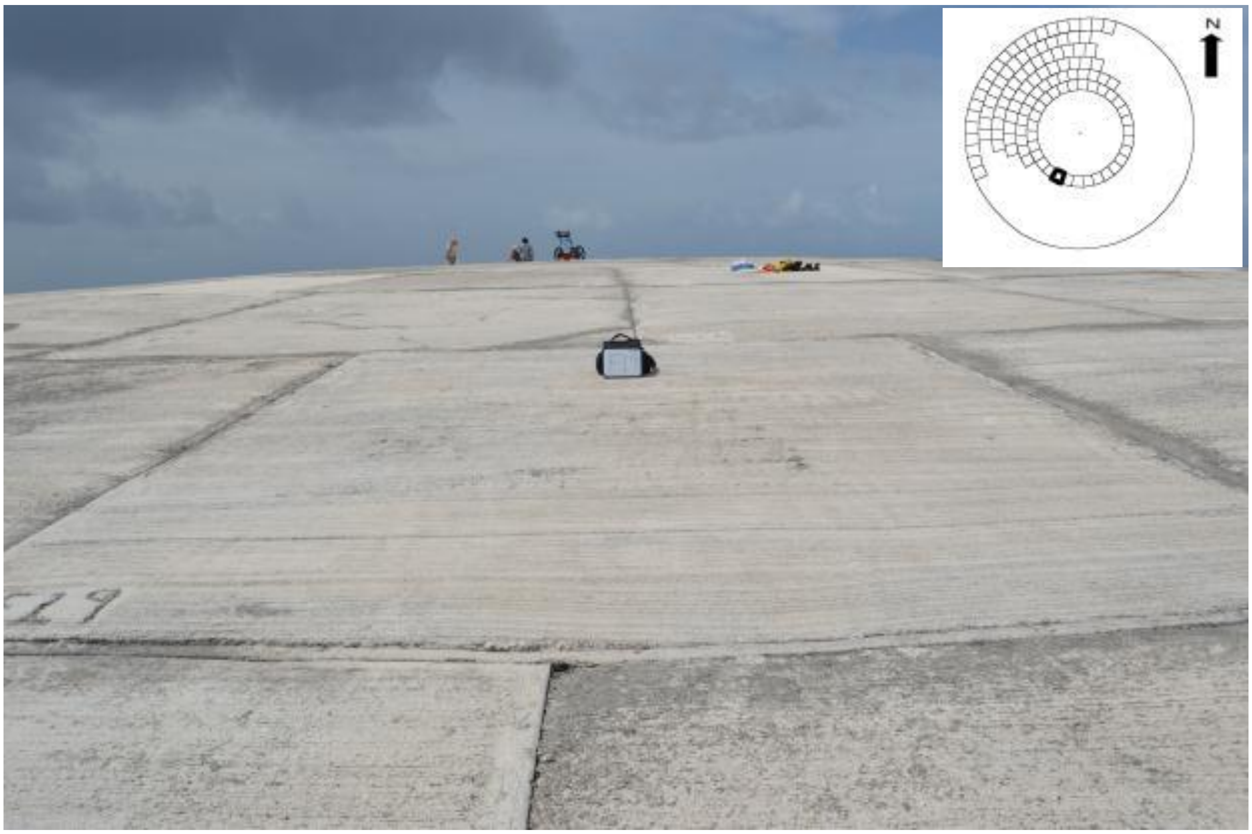
Rooting vegetation removed from along the panel seams. There is a surface crack traversing up through the middle of the panel from a central position along the bottom seam.



CAP SECTION LOCATION: Panel F19

Description

No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel F19_duplicate (F20)

Description

The panel has a rough and weathered appearance. There is a surface crack traveling up the panel for about 2 meters from a point adjacent to the corner intersection of the E19/E20 panels on the ring rows below.

CAP SECTION LOCATION: Panel F21

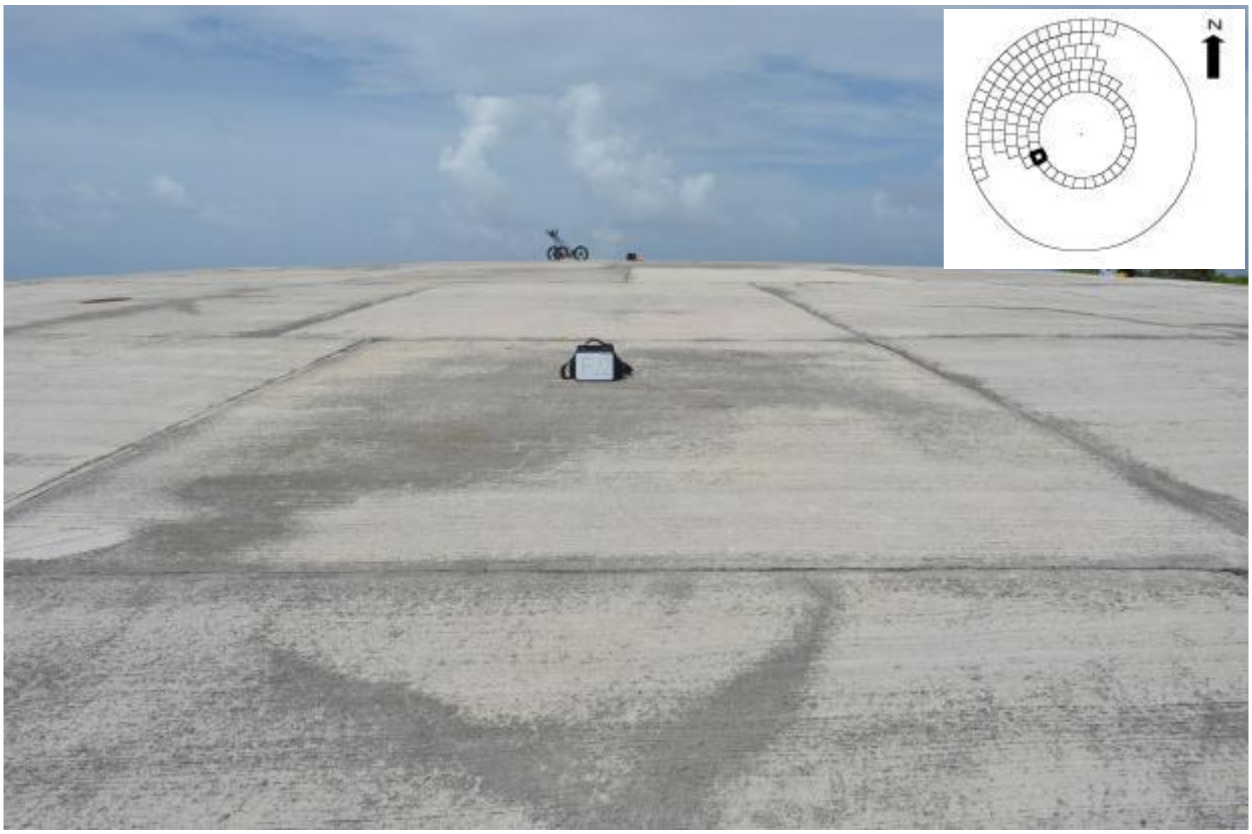
Description

No significant or obvious interior cracks or spall elements identified.

CAP SECTION LOCATION: Panel F22

Description

No significant or obvious interior cracks or spall elements identified. Some minor spalling/chipping of concrete in the upper left-hand corner of the panel.



CAP SECTION LOCATION: Panel F23

Description

No significant or obvious interior cracks or spall elements identified.

CAP SECTION LOCATION: Panel F24

Description

The panel has a rough and weathered appearance. No significant or obvious interior cracks or spall elements identified. Some spalling/chipping of concrete in the bottom left-hand corner of the panel.

CAP SECTION LOCATION: Panel F25

Description

No significant or obvious interior cracks or spall elements identified. Some spalling/chipping of concrete in the bottom right and left-hand corners of the panel. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel F26

Description

No significant or obvious interior cracks or spall elements identified. Some spalling/chipping of concrete in the bottom right-hand corner. Rooting vegetation removed from along the panel seams.

CAP SECTION LOCATION: Panel F27

Description

The panel has a rough and weathered appearance. Multiple surface cracks observed crisscrossing up through the middle of the panel with intersections reaching out to the bottom, top, left and right-hand edges. Some spalling/chipping of concrete along the panel seams.

CAP SECTION LOCATION: Panel F28

Description

No significant or obvious interior cracks or spall elements identified. Some spalling/chipping of concrete along the upper right-hand seam of the panel.

CAP SECTION LOCATION: Panel F29

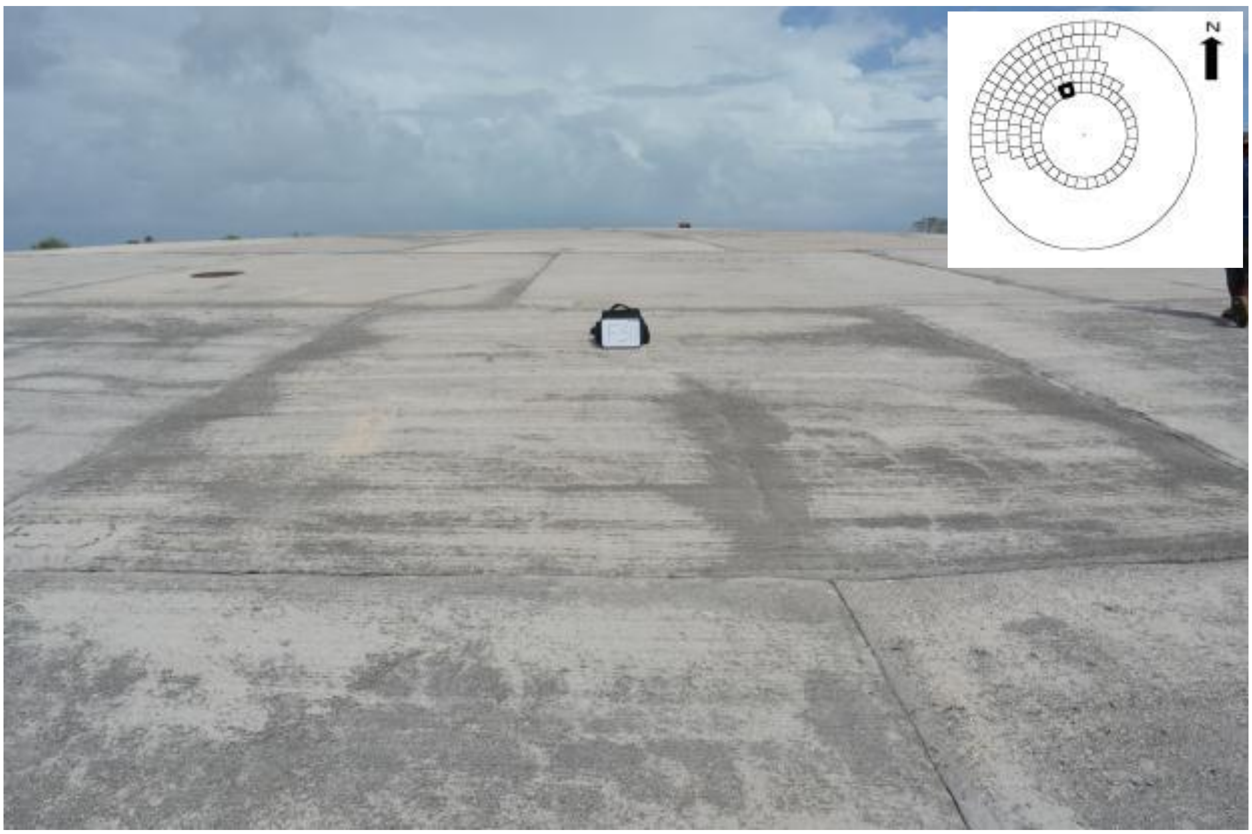
Description

The panel has a rough weathered appearance. No significant cracks or spall elements identified. Some spalling/chipping of concrete in upper right-hand corner and along the seams of the panel.

CAP SECTION LOCATION: Panel F30

Description

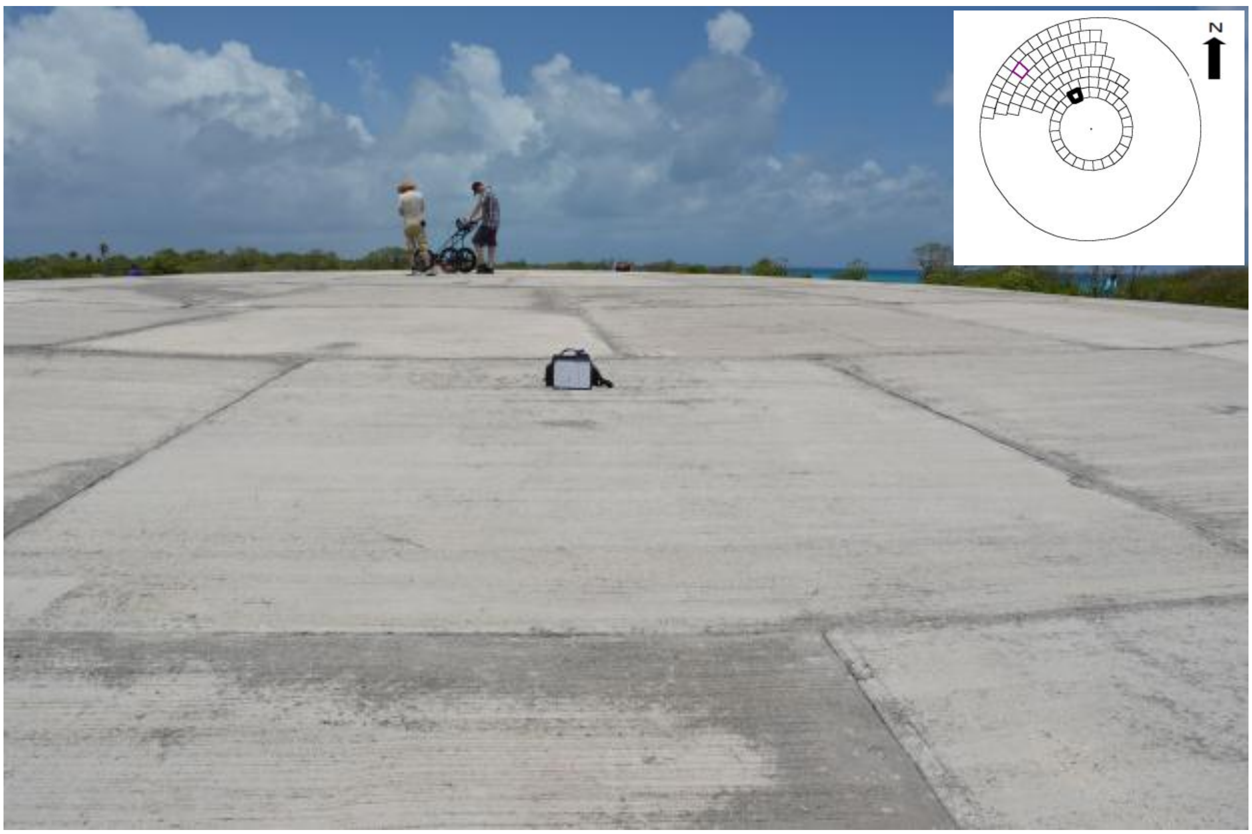
No significant cracks or spall elements identified. Some spalling/chipping of concrete in upper left-hand corner and along the seams of the panel.



CAP SECTION LOCATION: Panel G1

Description

No significant or obvious interior cracks or spall elements identified. Minor spalling/cracking of concrete in the upper left-hand corner of the panel.



CAP SECTION LOCATION: Panel G2

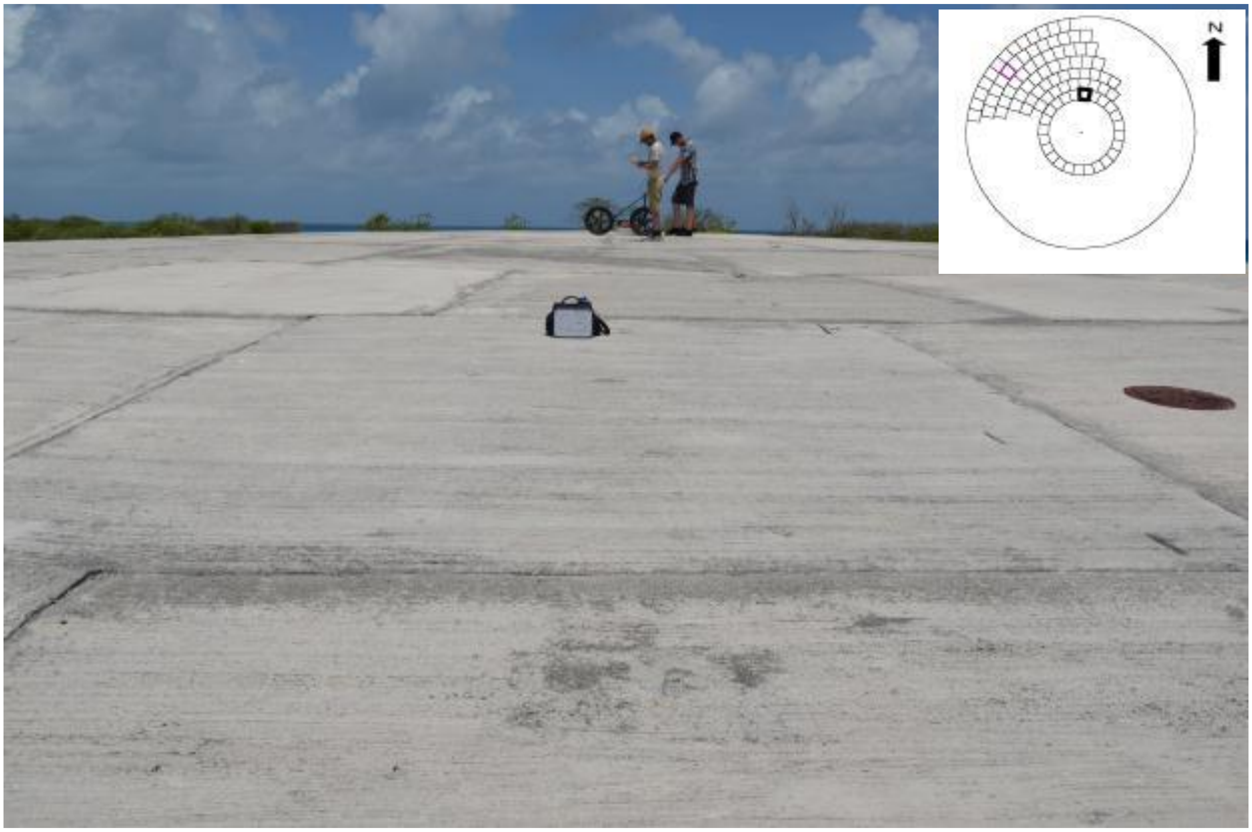
Description

Surface crack observed traversing across the bottom right-hand corner of the panel. The crack intersects the bottom and left-hand seams of the panel at a distance of about 1.2 meters and 2 meters from the right-hand corner, respectively. The panel contains a vertical elevation benchmark.

CAP SECTION LOCATION: Panel G3

Description

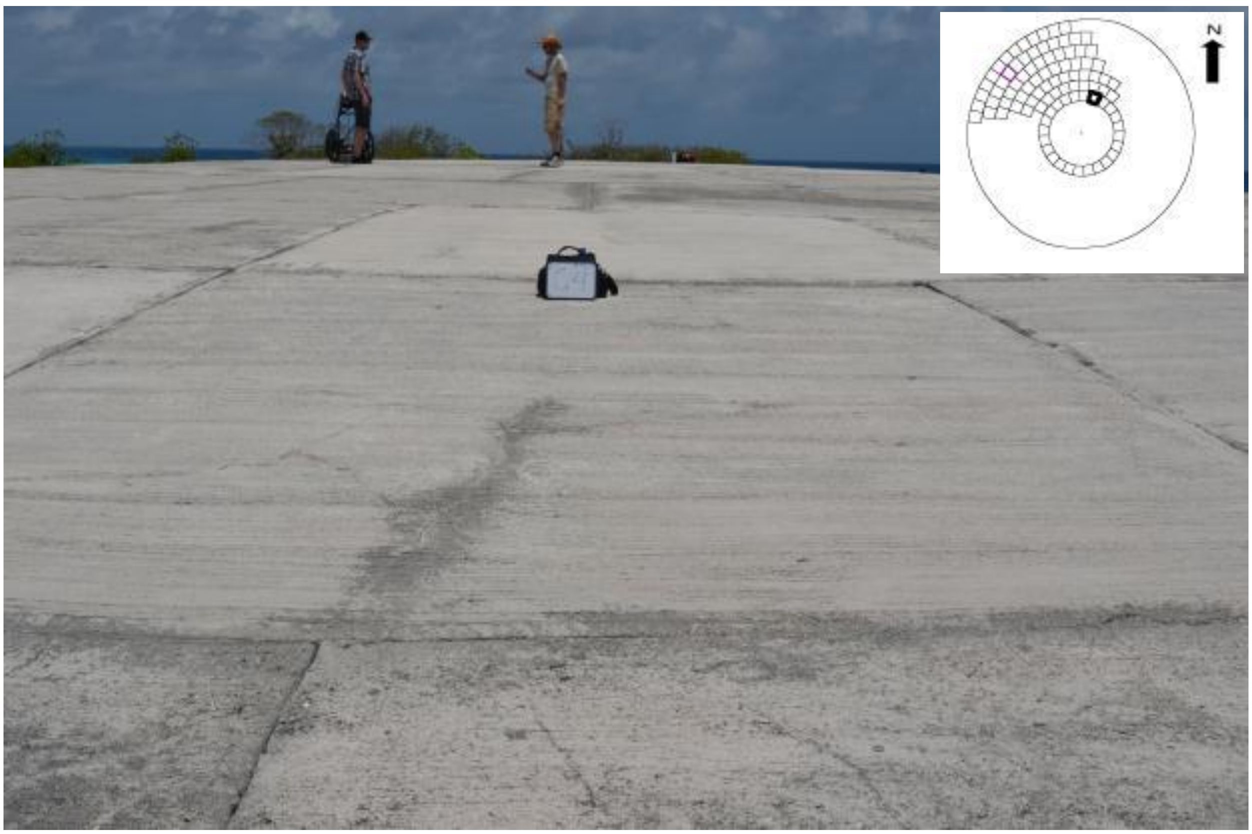
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel G4

Description

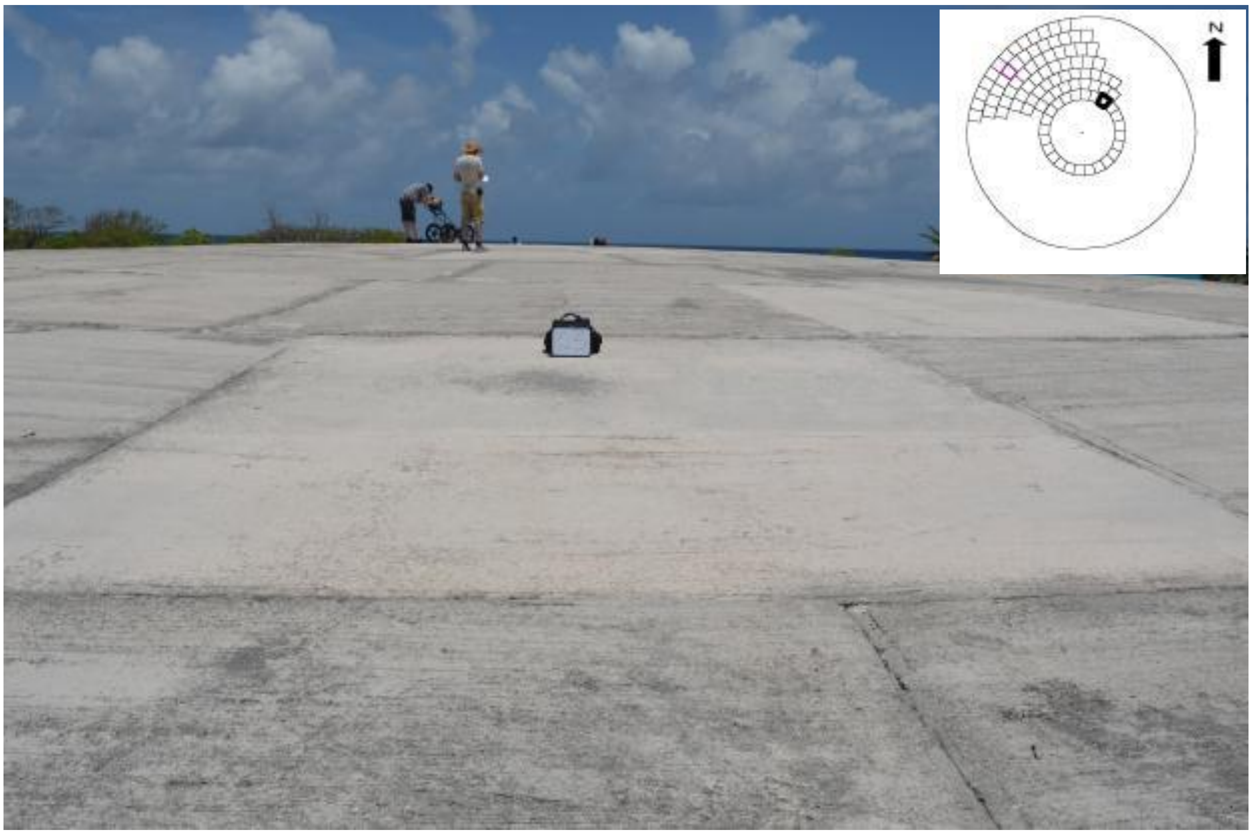
Multiple surface cracks crisscrossing the bottom portion of the panel. Minor spalling/chipping of concrete observed in the upper left-hand corner of the panel.



CAP SECTION LOCATION: Panel G5

Description

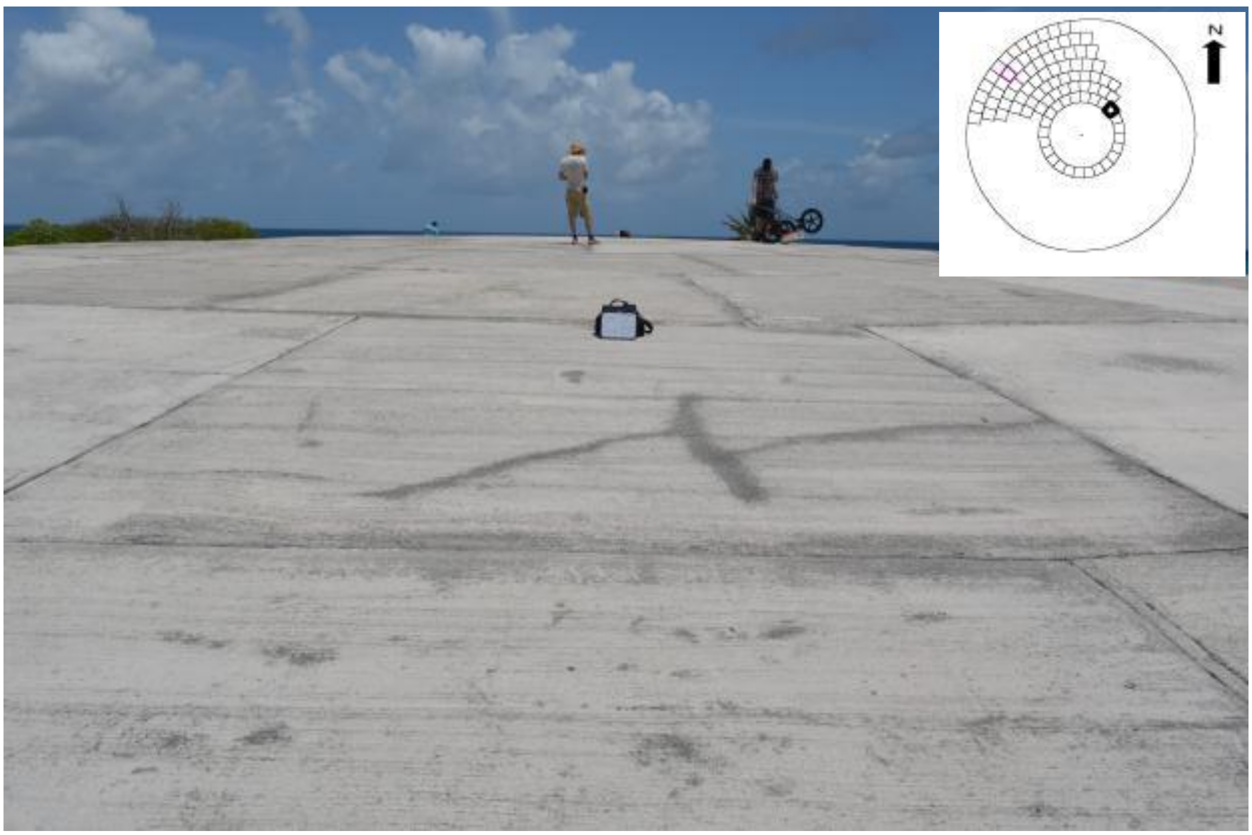
Minor surface crack observed traversing up from a central position along the bottom seam of the panel for a distance of about 2 meters.



CAP SECTION LOCATION: Panel G6

Description

There is a surface crack on the bottom, right-hand side of the panel along with a small weathered out void (or hole) in the concrete. The void is about 5 centimeters long and 1.5 centimeters wide.



CAP SECTION LOCATION: Panel G7

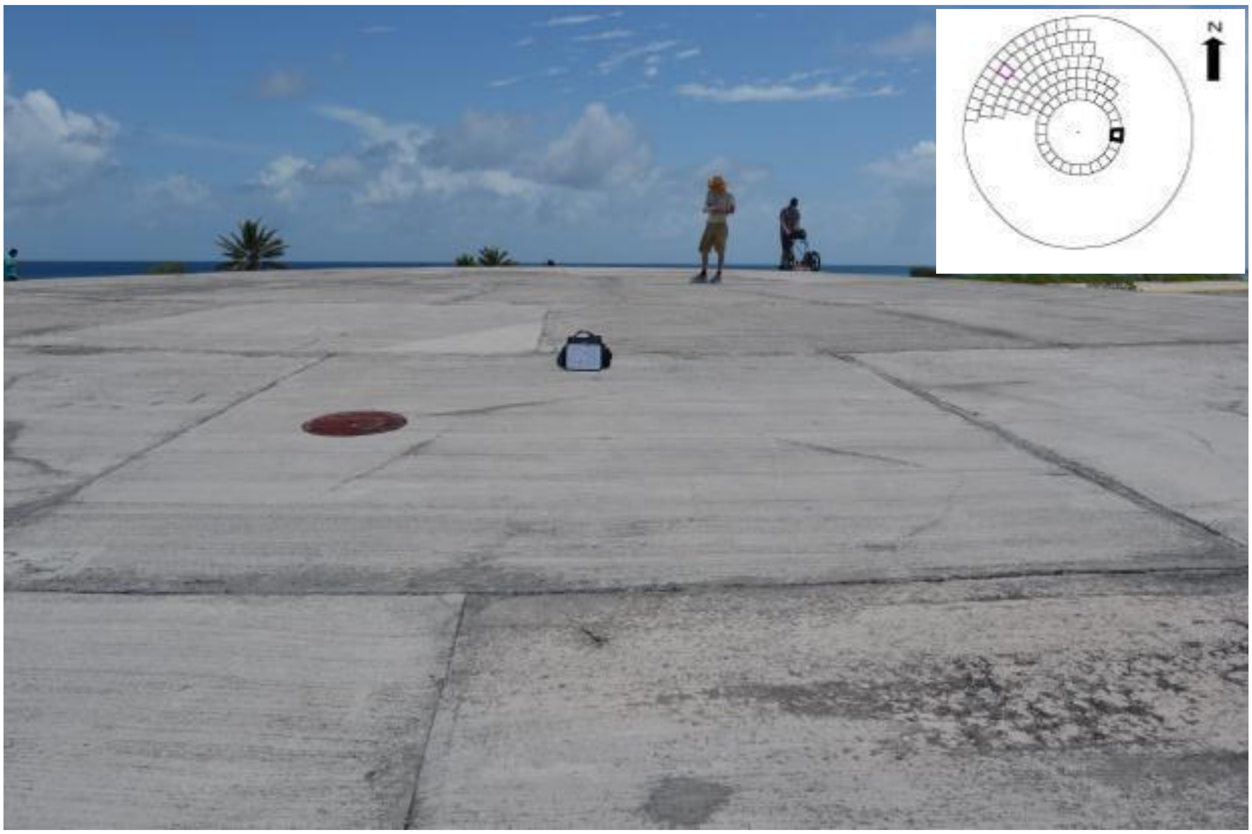
Description

A surface crack identified traversing up through the center of the panel with branches out to the left and right-hand sides of the panel.

CAP SECTION LOCATION: Panel G8

Description

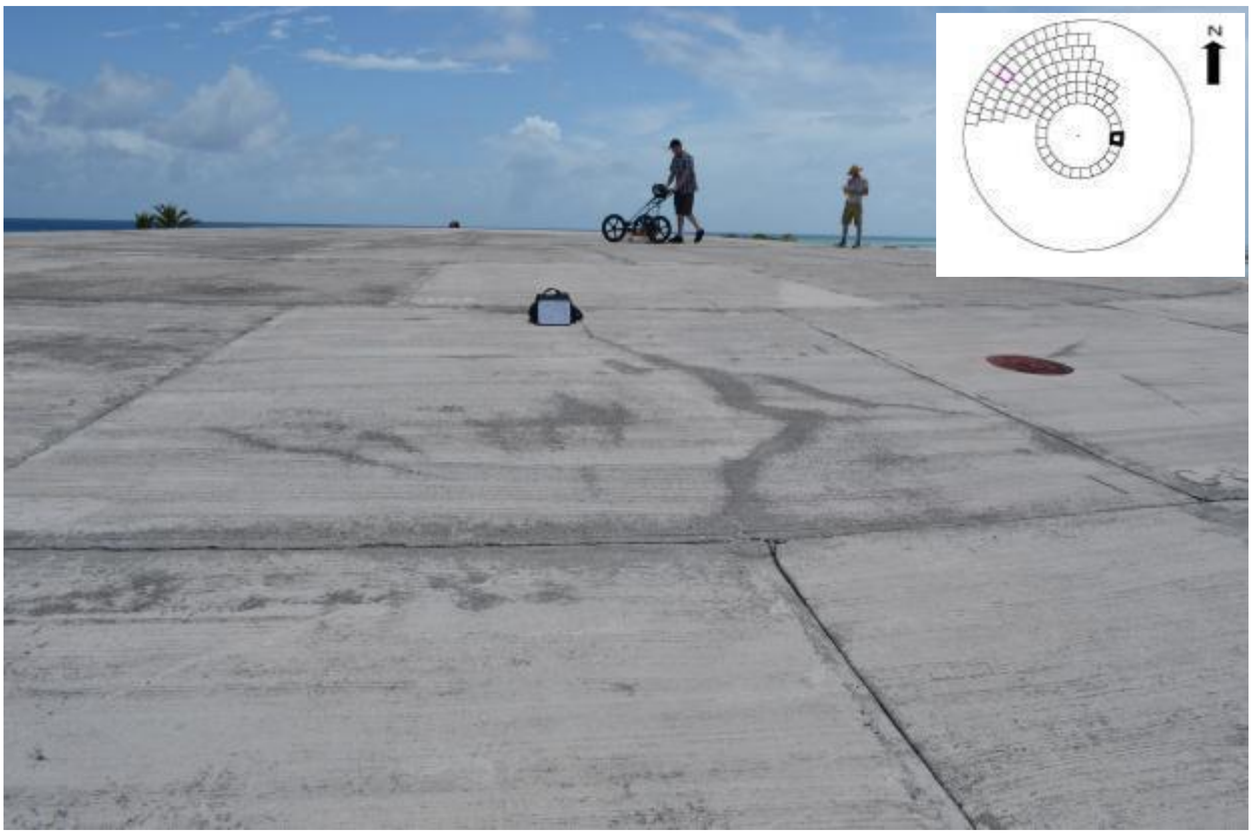
A fork shaped surface crack identified extending out from the right-hand seam commencing about 1.2 meters from the bottom of the panel. The panel contains a vertical elevation benchmark.



CAP SECTION LOCATION: Panel G9

Description

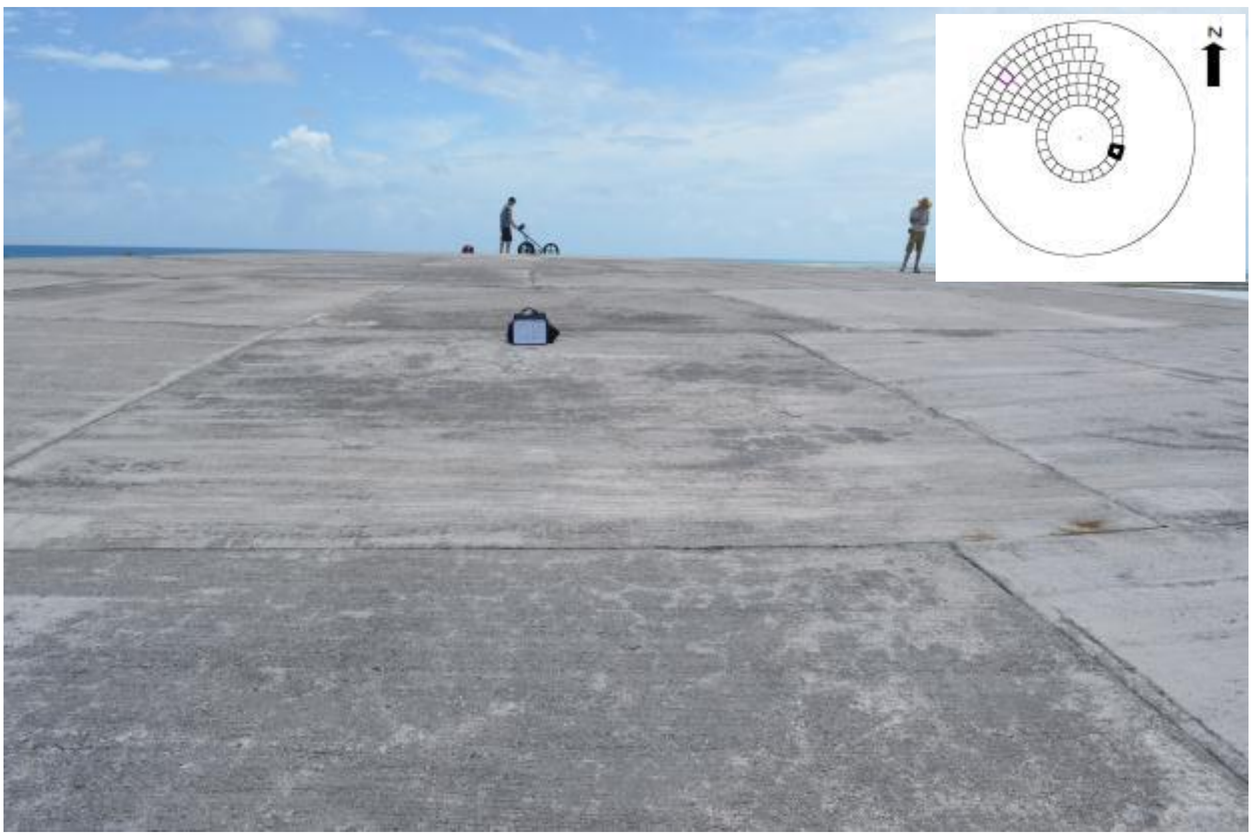
No significant or obvious interior cracks or spall elements identified. Minor spalling/cracking of concrete in the upper right-hand corner of the panel.



CAP SECTION LOCATION: Panel G10

Description

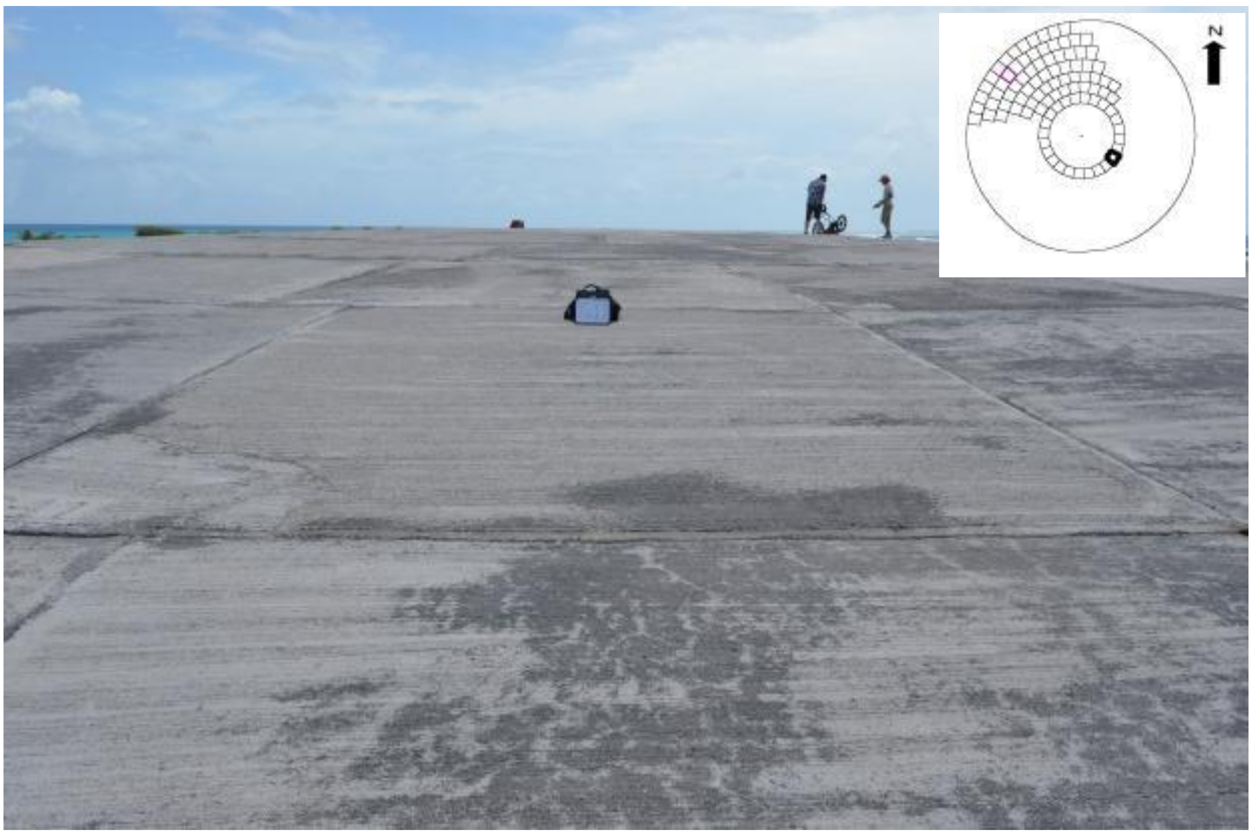
No significant or obvious interior cracks or spall elements identified. Minor spalling/cracking of concrete in the upper left-hand corner of the panel.



CAP SECTION LOCATION: Panel G11

Description

The panel contains no significant or obvious interior cracks or spall elements. Rooting vegetation removed from along the panel seams. Minor spalling/cracking of concrete in the lower right-hand corner of the panel.



CAP SECTION LOCATION: Panel G12

Description

The panel contains no significant or obvious interior cracks or spall elements. Please note that there are no panels labeled G13 through G18.

CAP SECTION LOCATION: Panel G19

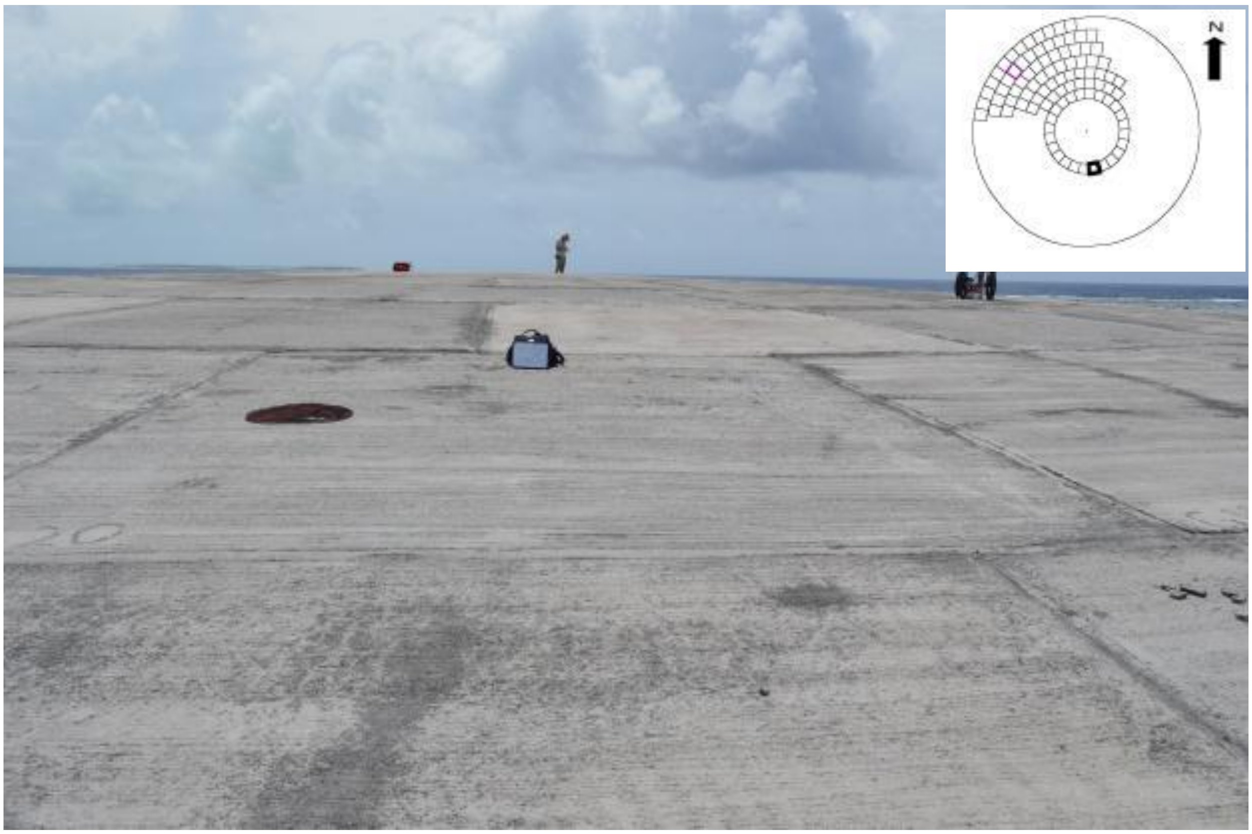
Description

Surface crack observed extending up through the middle of the panel intersecting the upper seam at corner H11/H12 on the ring row above. Panel contains a capped concrete bore-hole (CD-6) from the 1980 NAS investigation.

CAP SECTION LOCATION: Panel G20

Description

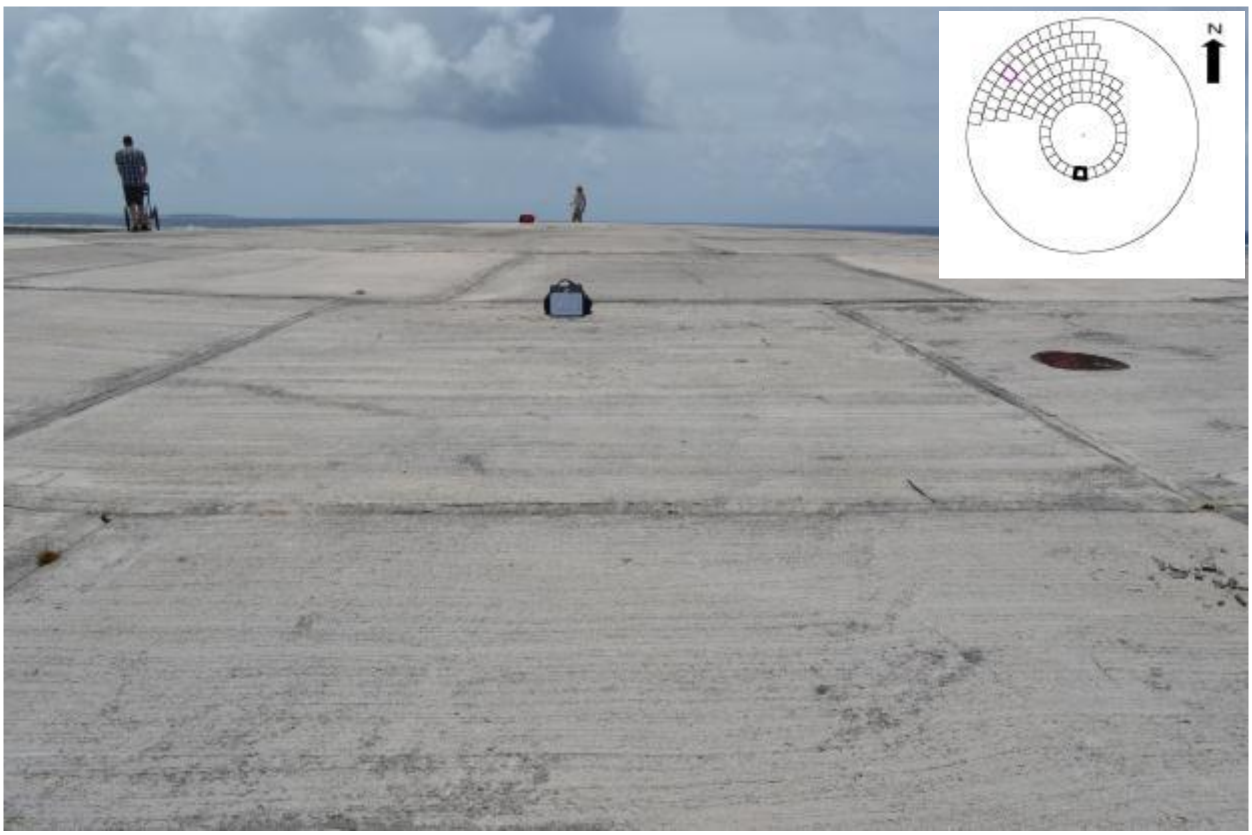
The panel contains no significant or obvious interior cracks or spall elements. Panel contains a vertical elevation benchmark.



CAP SECTION LOCATION: Panel G21

Description

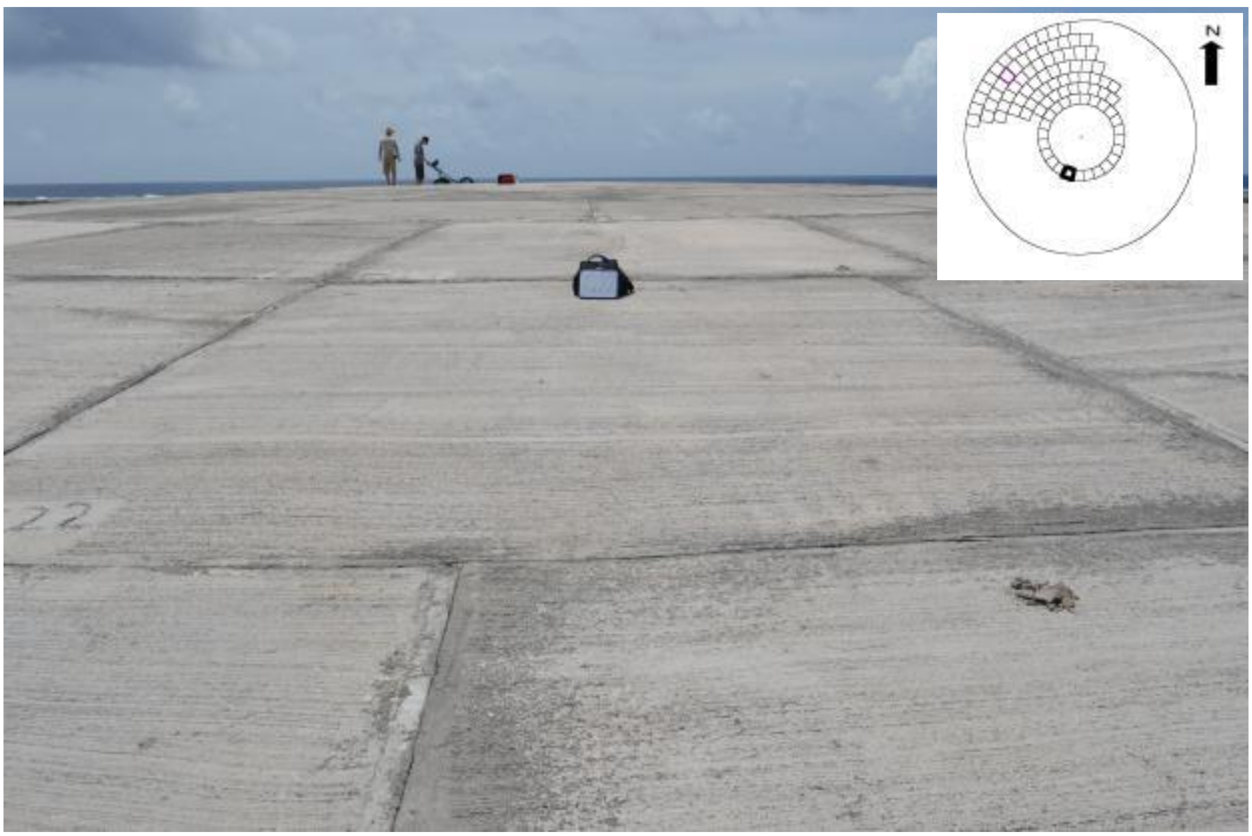
The panel contains no significant or obvious interior cracks or spall elements. Some minor spalling/chipping of concrete along the upper left-hand seam. A small void observed in the concrete close to the right-side seam (refer photo). There some indication that the cracks along the panel joints are becoming more prominent compared with other panels contained in this ring row.



CAP SECTION LOCATION: Panel G22

Description

The panel contains no significant or obvious interior cracks or spall elements. The cracks opening up along the panel joints appear to be a little prominent compared with other panels located in this ring row.



CAP SECTION LOCATION: Panel G23

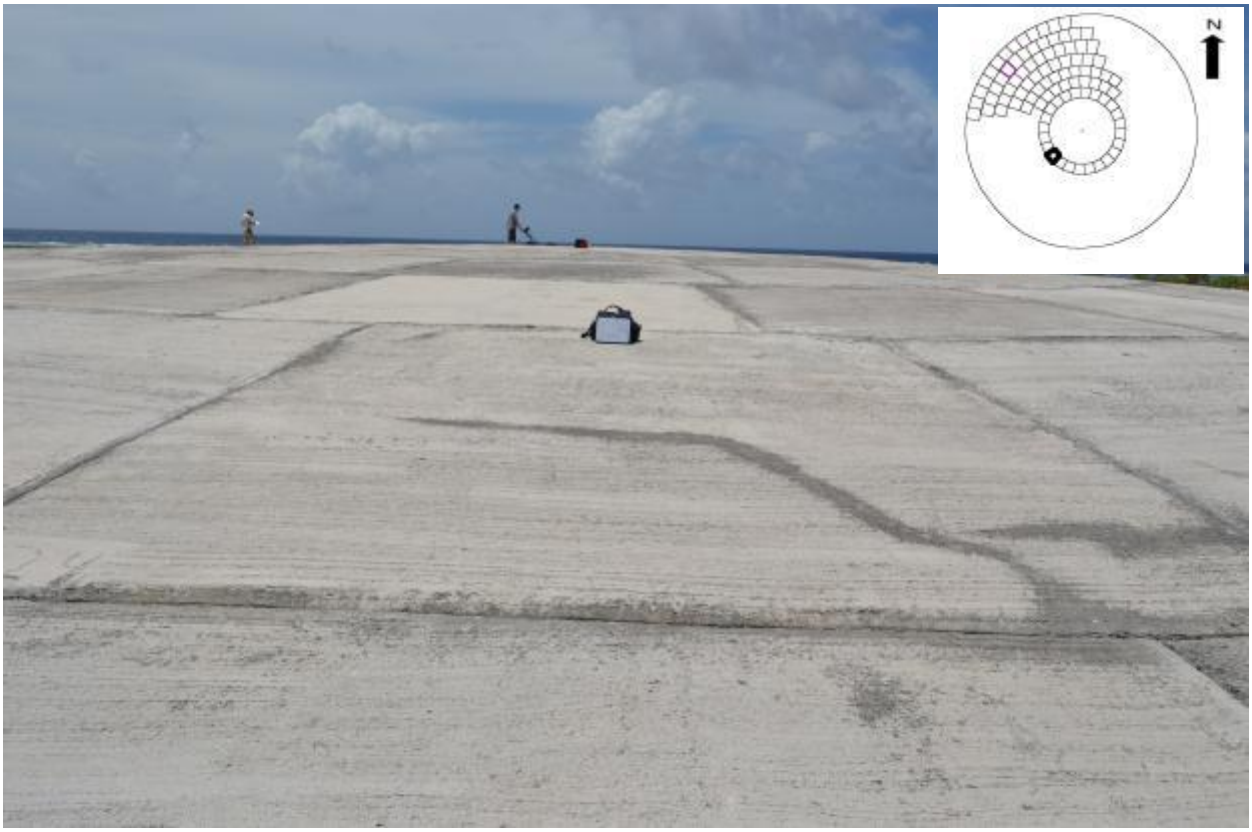
Description

The panel contains no significant or obvious interior cracks or spall elements. Some spalling/cracking of concrete along the bottom left-hand corner of the panel.

CAP SECTION LOCATION: Panel G24

Description

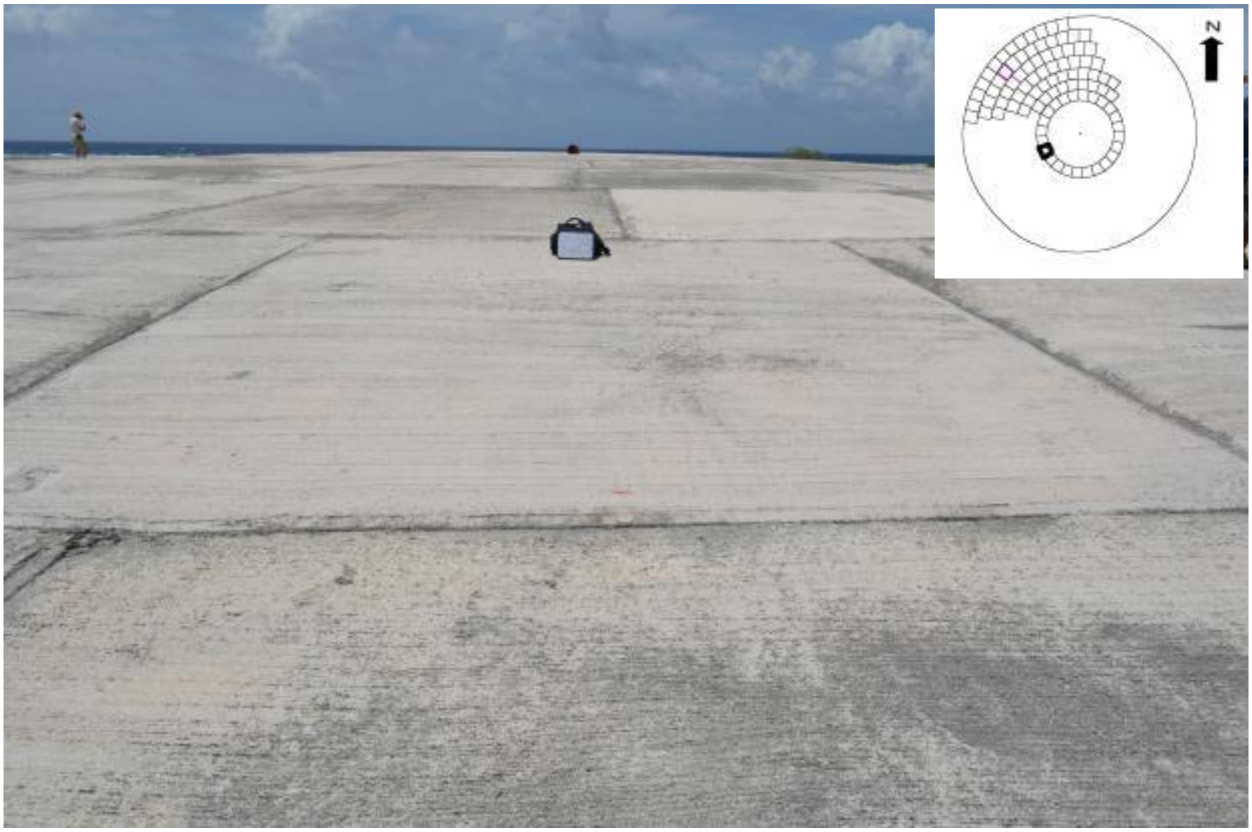
Some spalling/cracking of concrete observed in the upper left-hand corner of the panel. Minor crack observed about 1.2 meters from the bottom right-hand corner and traversing up the face of the panel for a distance of about 5 meters.



CAP SECTION LOCATION: Panel G25

Description

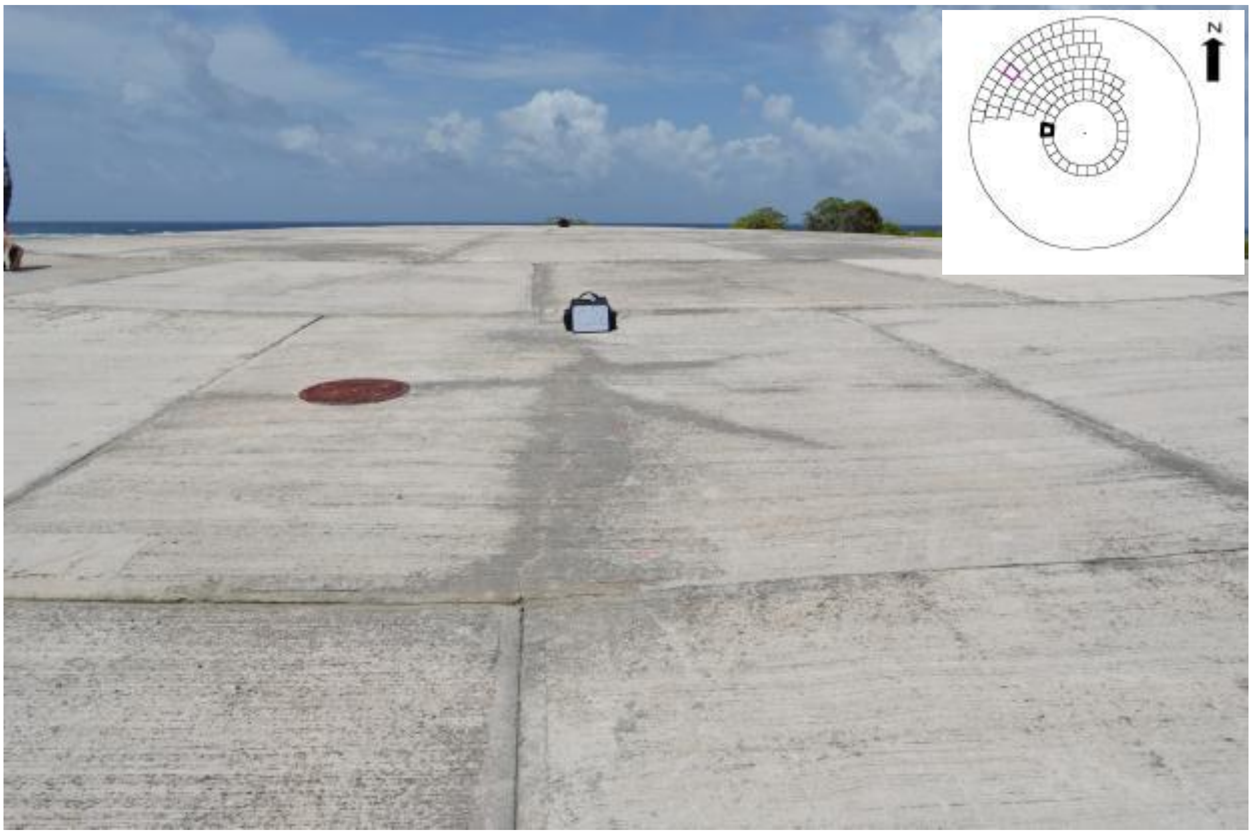
The panel contains no significant or obvious interior cracks or spall elements.



CAP SECTION LOCATION: Panel G26

Description

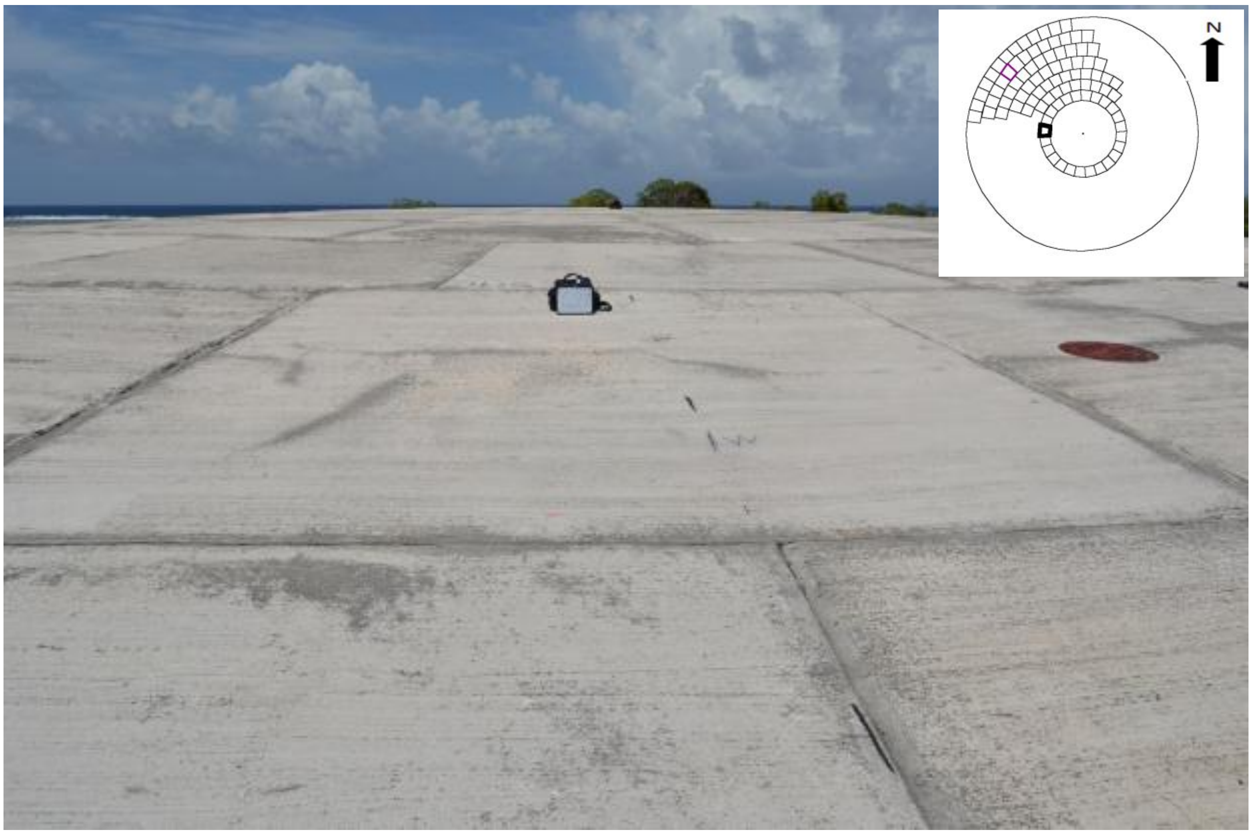
Surface crack observed traversing up through the middle of the panel with a fork branching out to the left at a mid-point up the panel. Panel contains a vertical elevation benchmark.



CAP SECTION LOCATION: Panel G27

Description

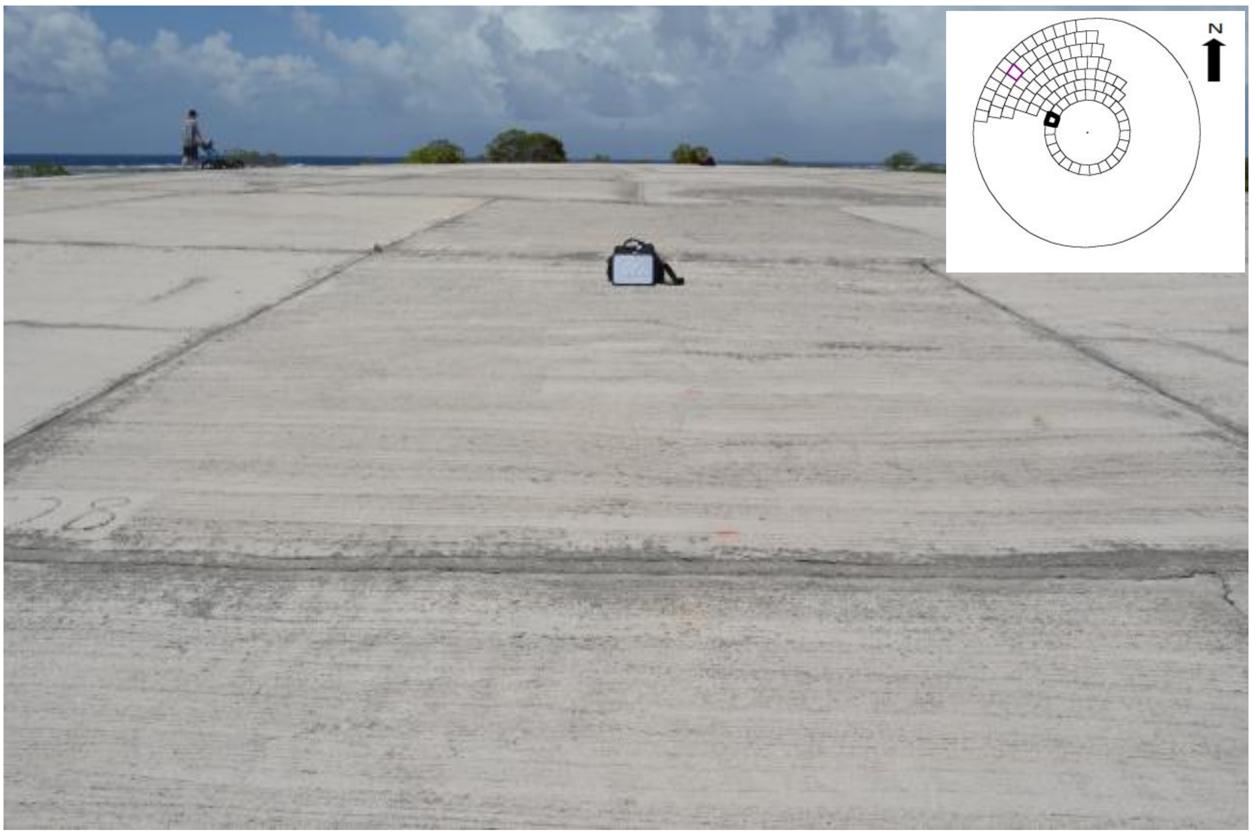
Some spalling/cracking of concrete observed in the upper left corner. Surface crack observed traversing across the panel.



CAP SECTION LOCATION: Panel G28

Description

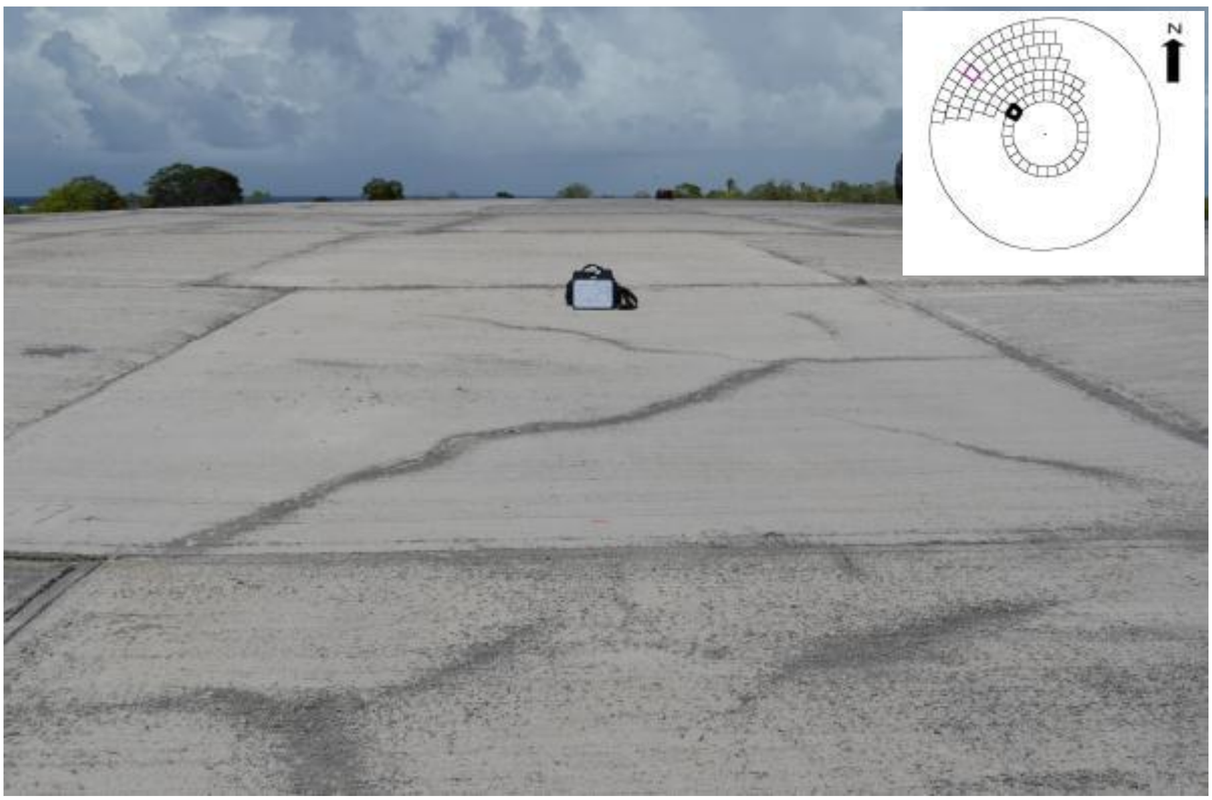
Rooting vegetation removed from along the panel seams. No significant or obvious interior cracks or spall elements identified with exception of spalling/cracking of concrete in the upper right-hand corner of the panel.



CAP SECTION LOCATION: Panel G29

Description

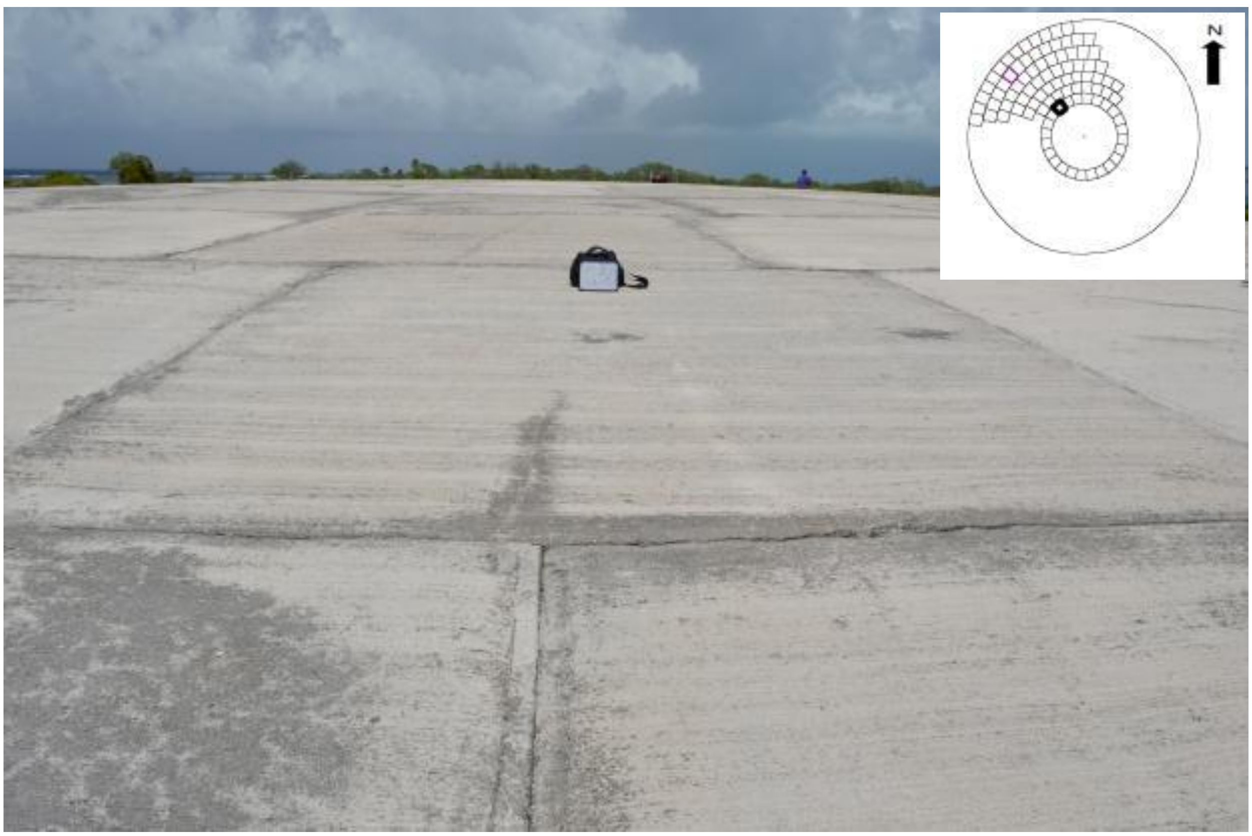
Surface crack observed extending up through the middle of the panel from the left side of the bottom seam towards the upper right-hand corner with forks branching out to the left and right sides at about a mid-point up the panel. Rooting vegetation removed from along the panel seams.



CAP SECTION LOCATION: Panel G30

Description

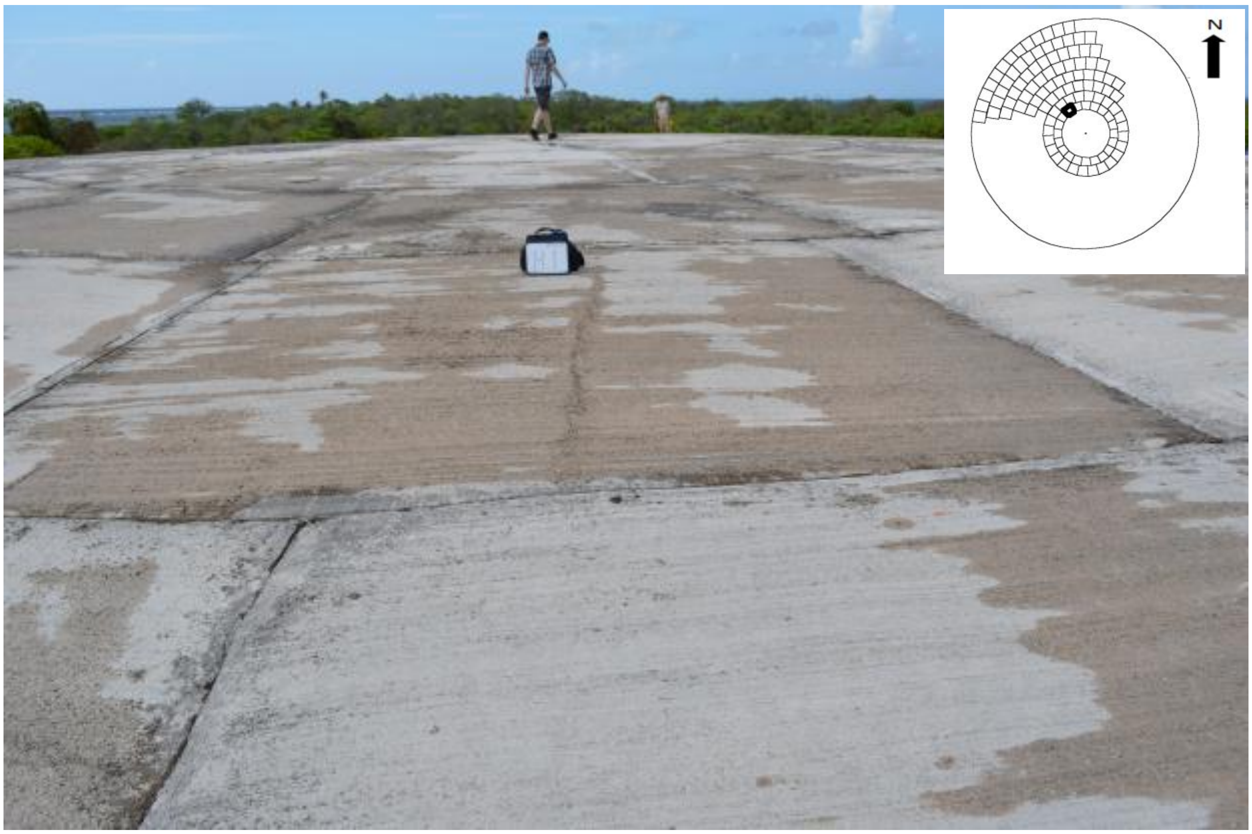
No significant or obvious interior cracks or spall elements identified with exception of very minor spalling/cracking of concrete along the top seam or panel joint. There are signs of a minor crack traversing up from the bottom seam near the intersecting corner of the panels on the ring row below.



CAP SECTION LOCATION: Panel H1

Description

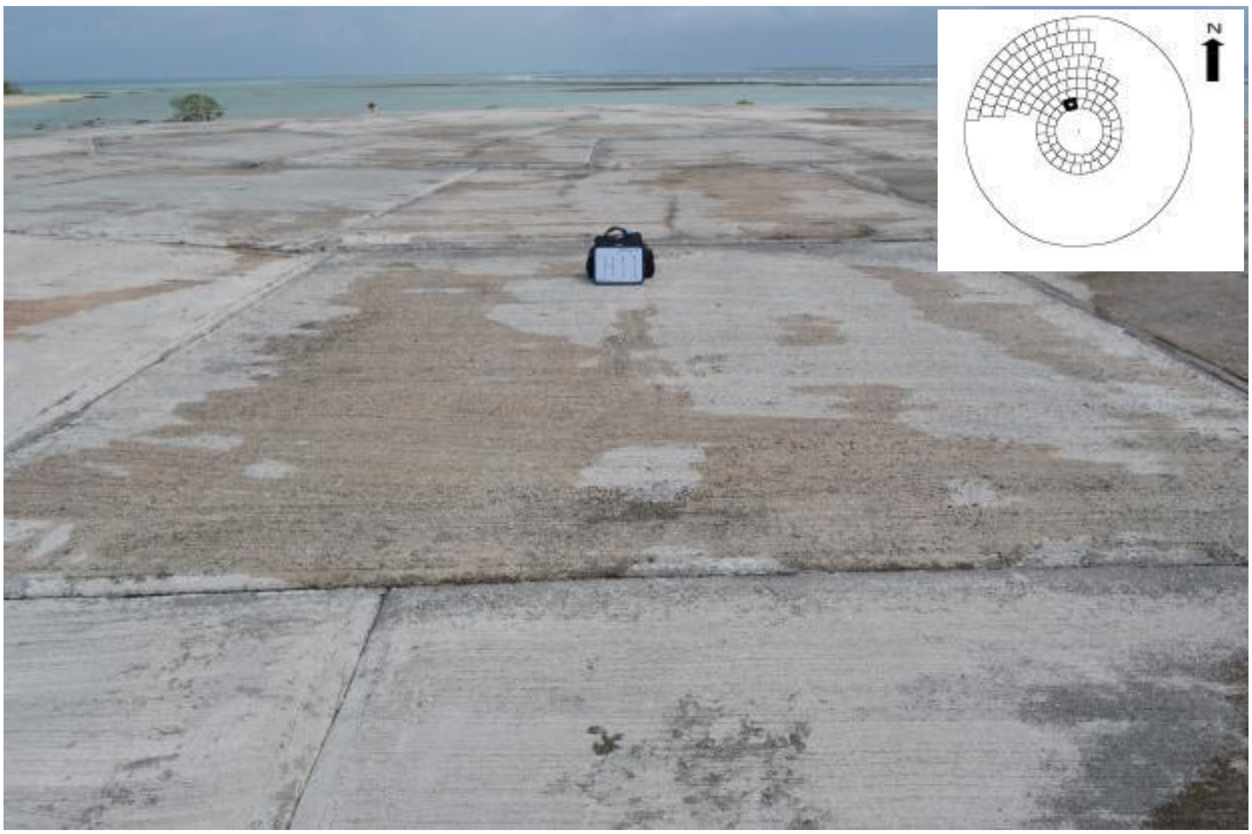
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel H2

Description

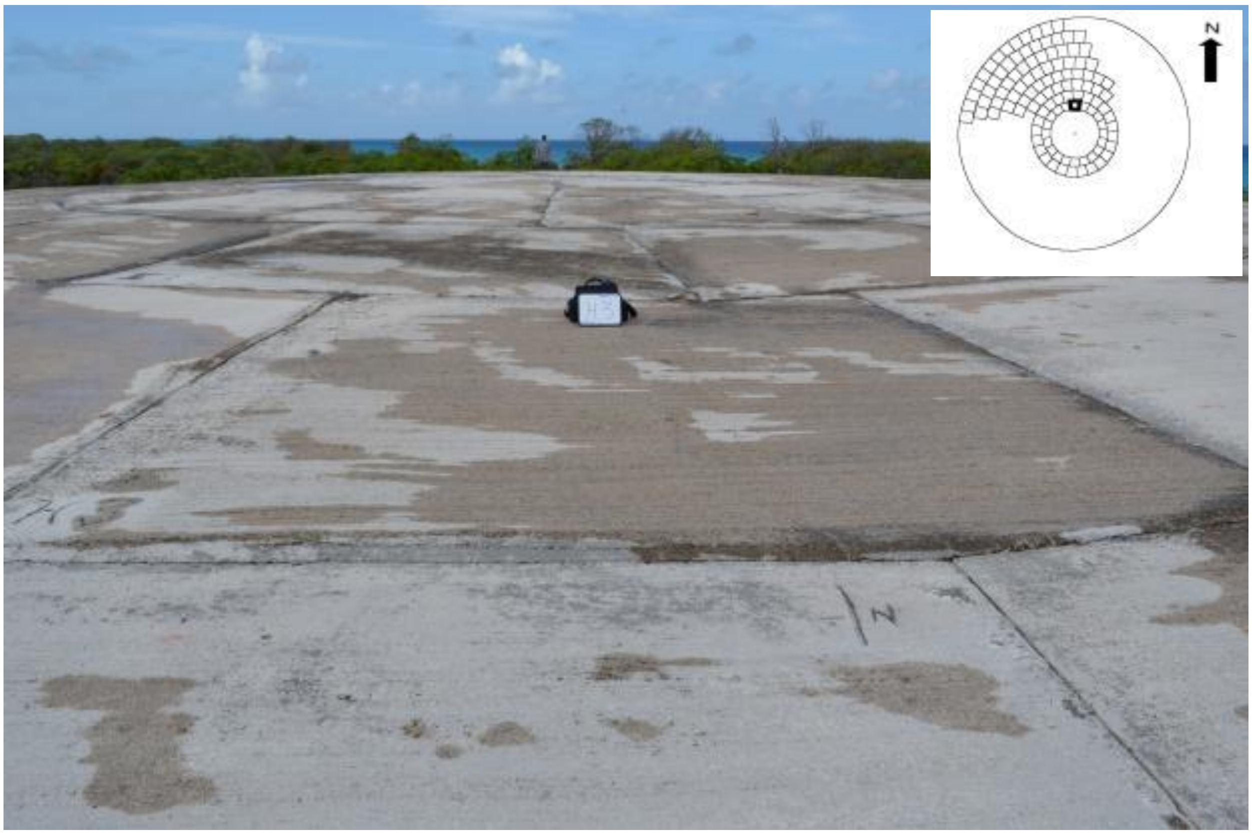
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel H3

Description

No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel H4

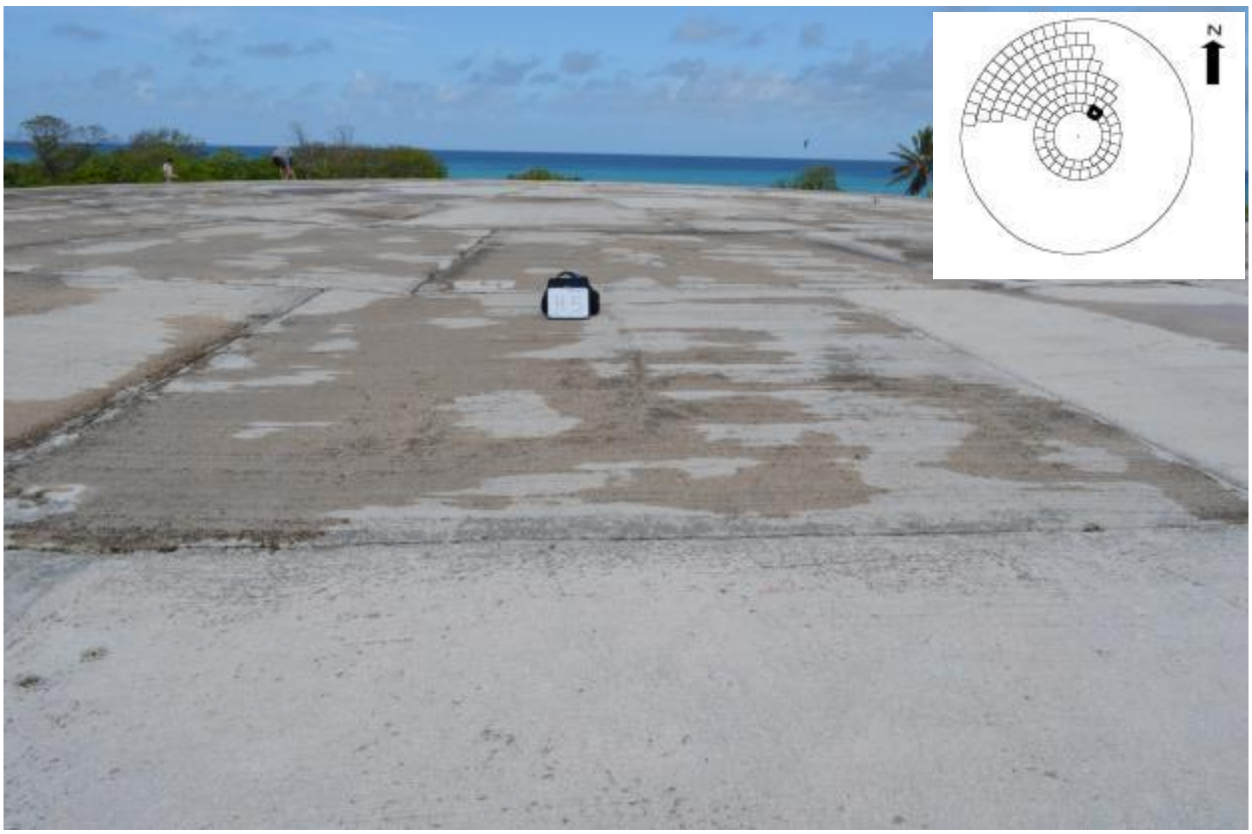
Description

No significant or obvious interior cracks or spall elements. Minor spalling/chipping of concrete in the bottom right-hand corner of the panel.

CAP SECTION LOCATION: Panel H5

Description

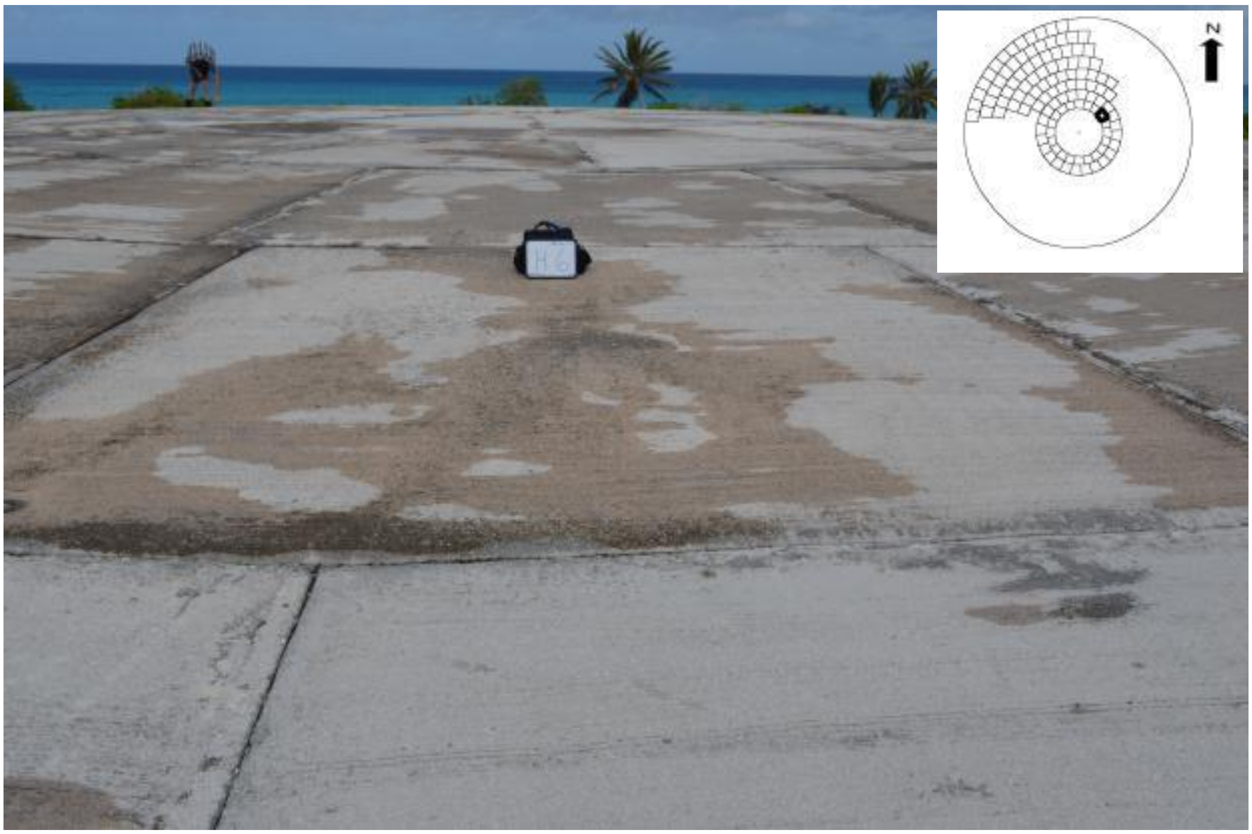
No significant or obvious interior cracks or spall elements identified. Minor spalling/chipping of concrete in the bottom left-hand corner of the panel.



CAP SECTION LOCATION: Panel H6

Description

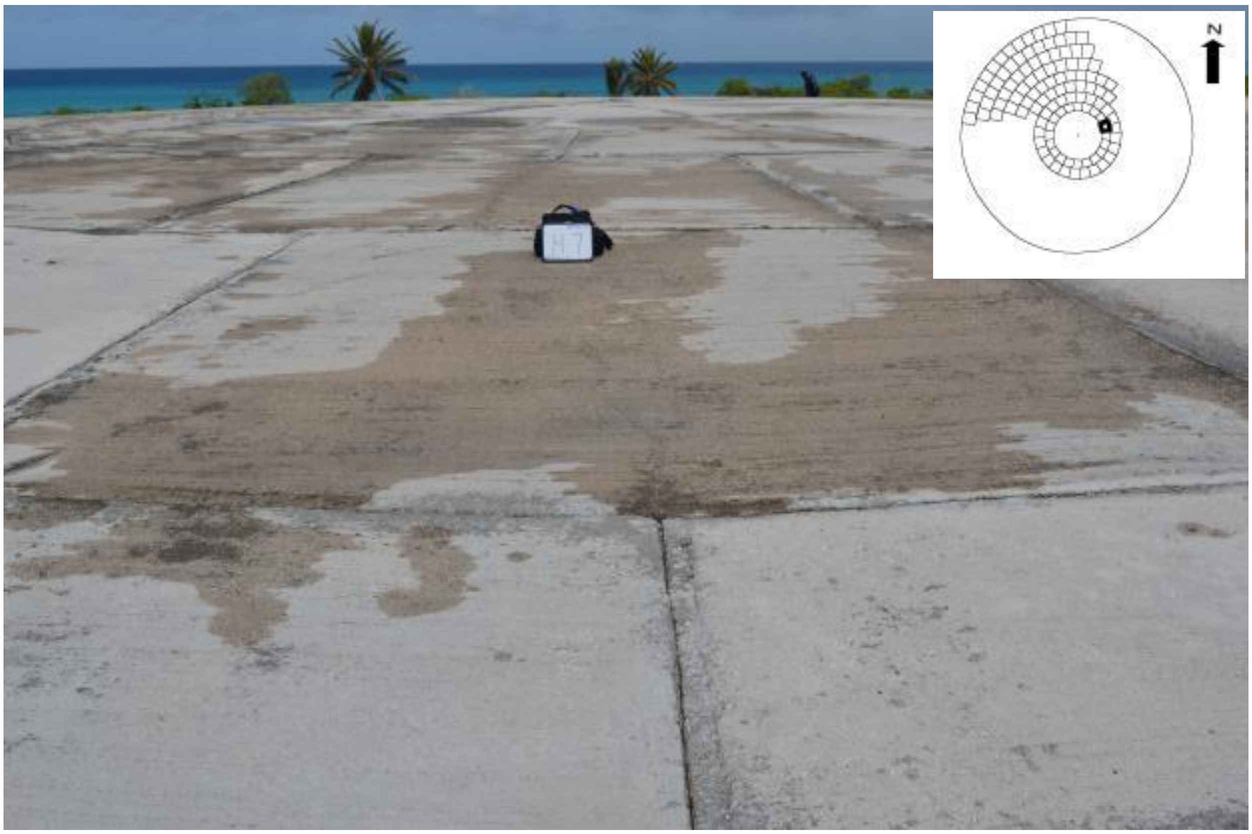
No significant or obvious interior cracks or spall elements identified. Minor spalling/chipping of concrete in the bottom right-hand corner of the panel.



CAP SECTION LOCATION: Panel H7

Description

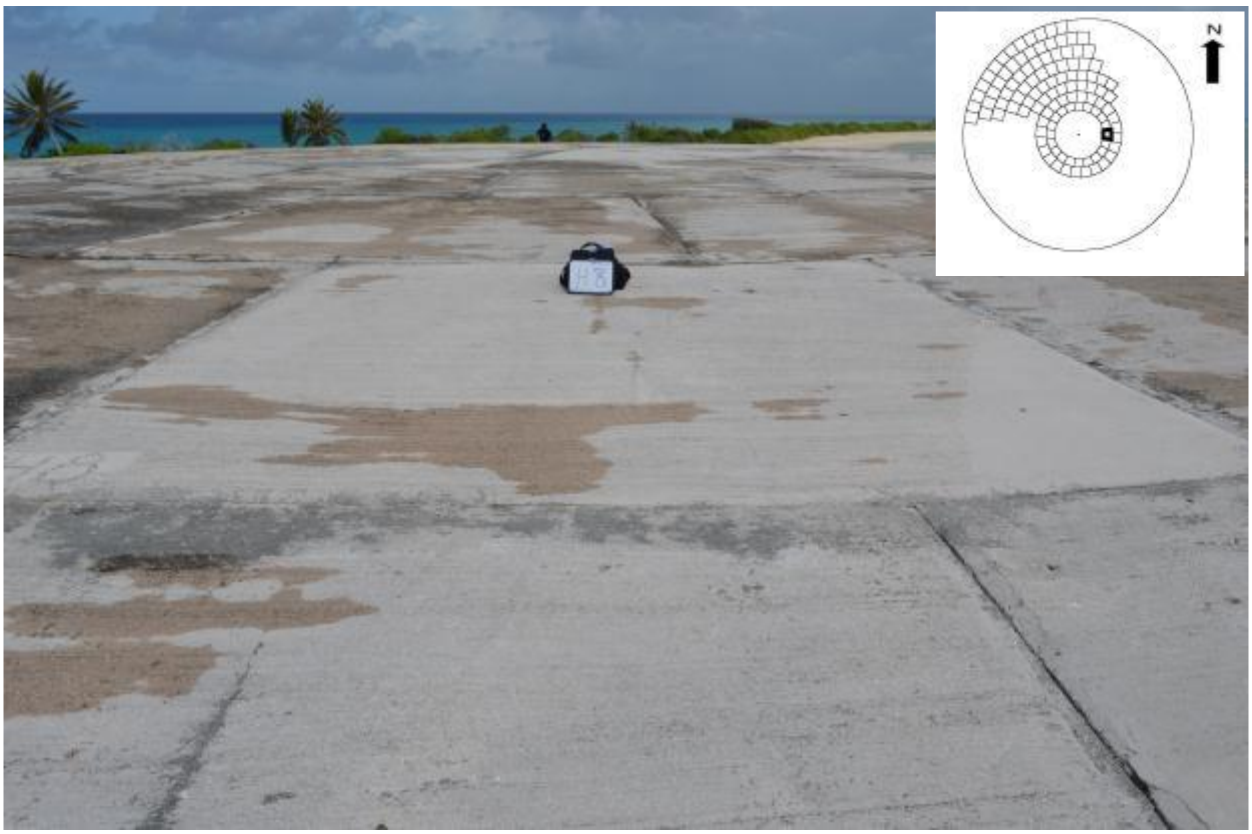
No significant or obvious interior cracks or spall elements identified. Minor spalling/chipping of concrete in the bottom right-hand corner of the panel.



CAP SECTION LOCATION: Panel H8

Description

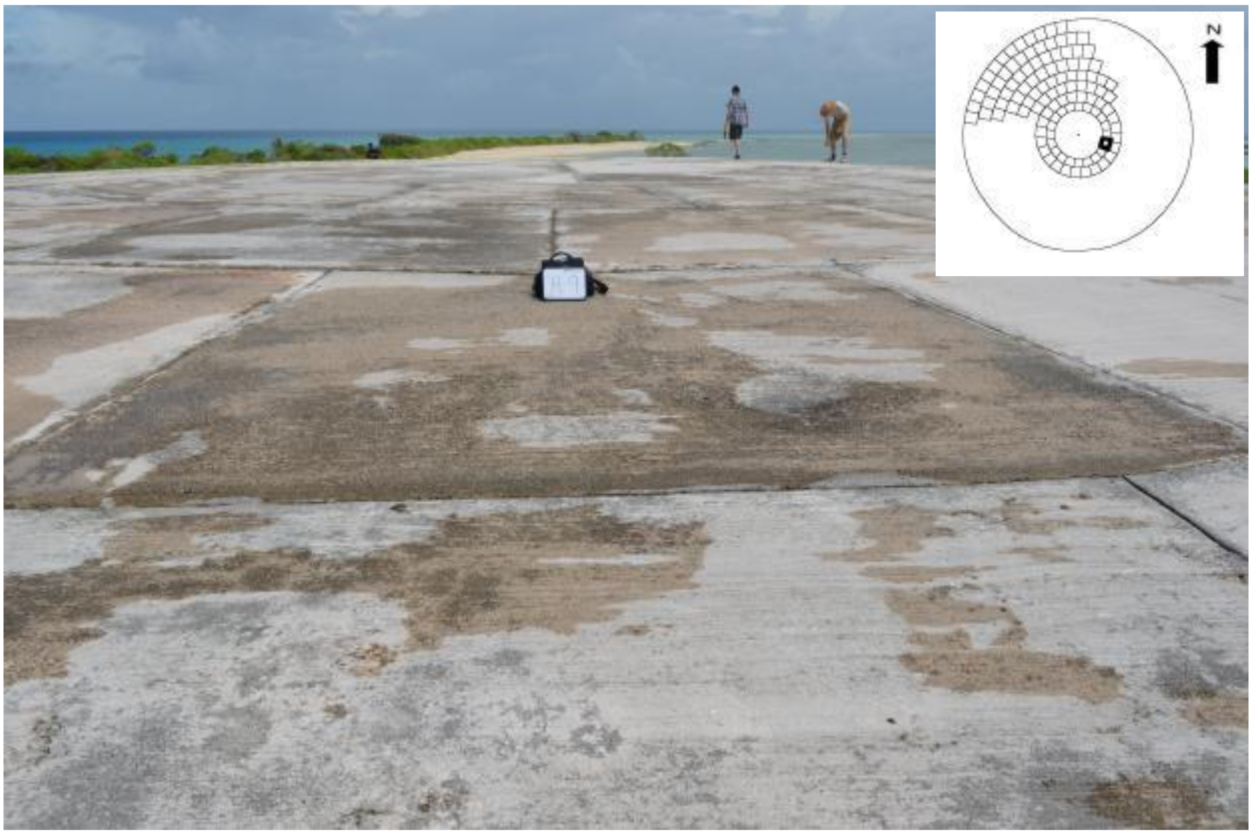
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel H9

Description

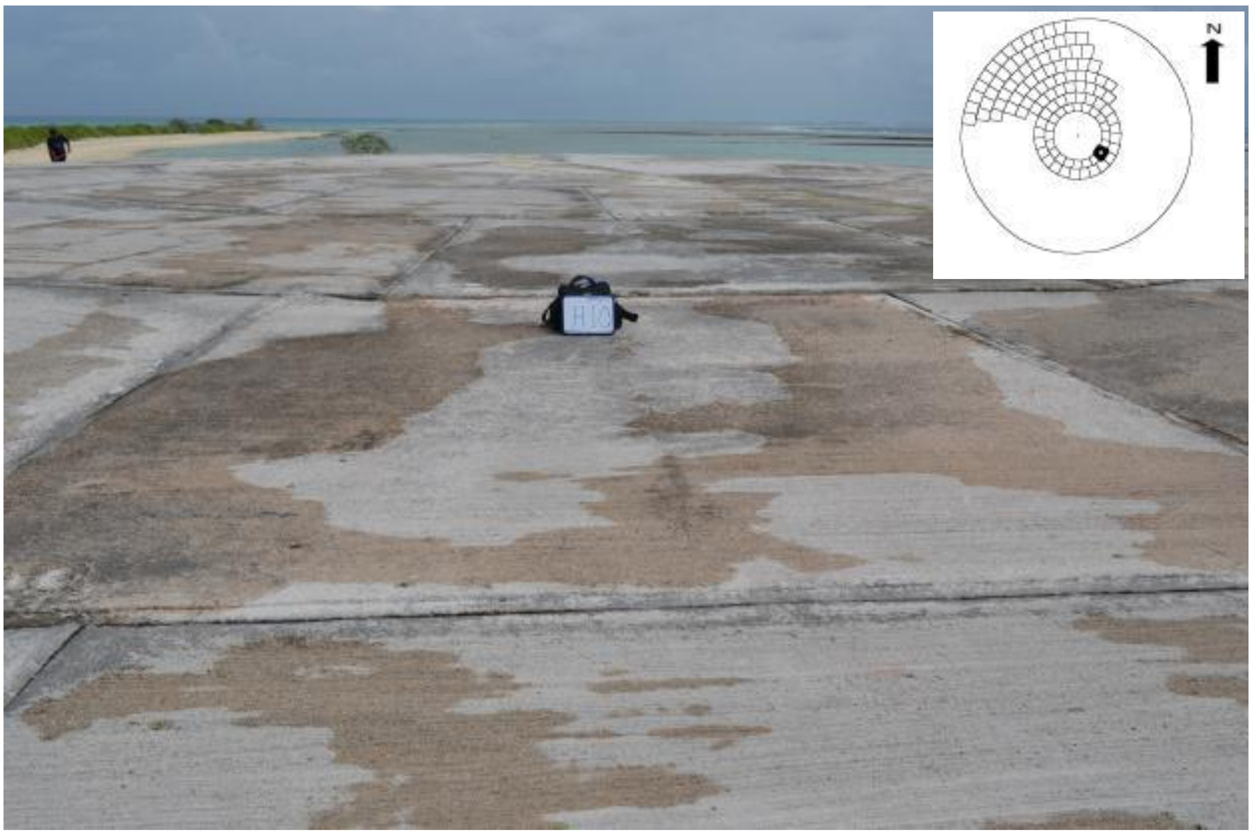
No significant or obvious interior cracks or spall elements identified. Minor spalling/chipping of concrete in the bottom right-hand corner.



CAP SECTION LOCATION: Panel H10

Description

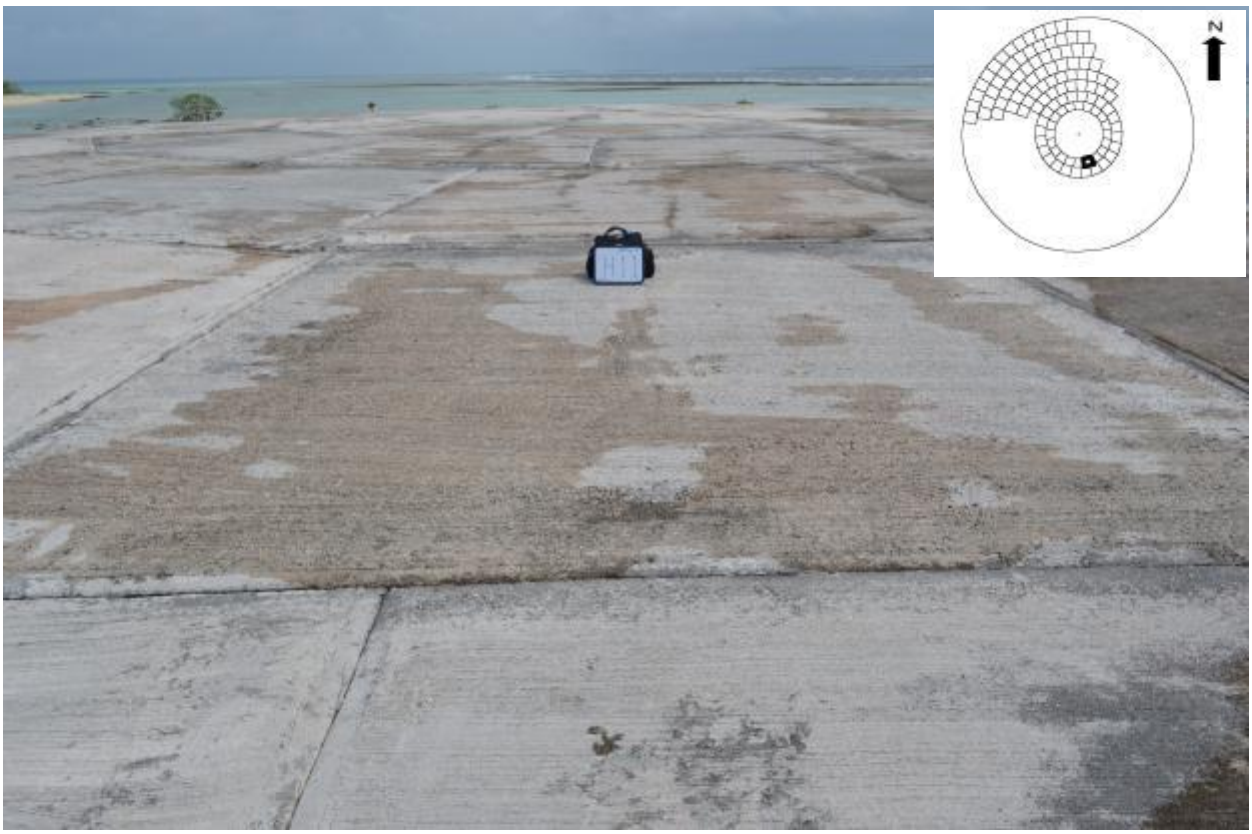
No significant or obvious interior cracks or spall elements identified. Minor spalling/chipping of concrete in the bottom right and left-hand corners of the panel.



CAP SECTION LOCATION: Panel H11

Description

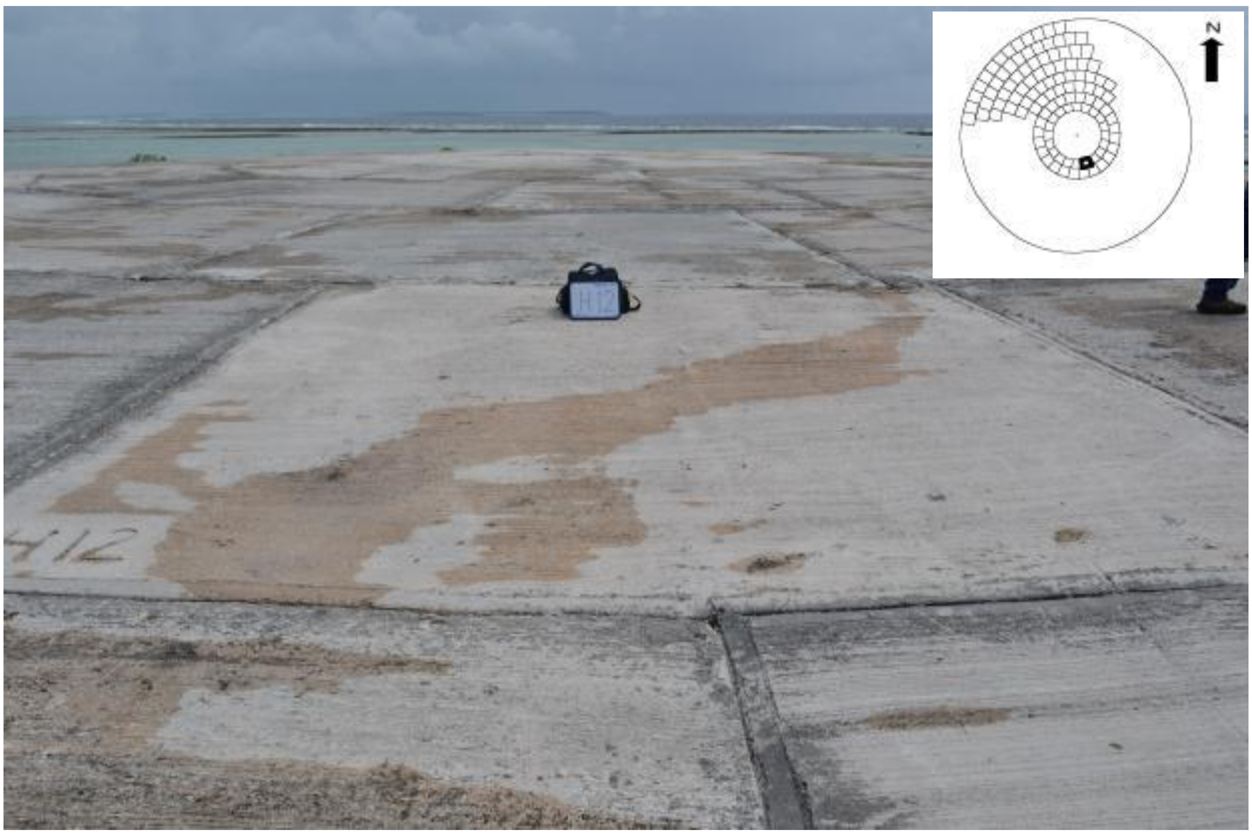
No significant or obvious interior cracks or spall elements identified. Minor spalling/chipping of concrete in the upper left-hand corner of the panel.



CAP SECTION LOCATION: Panel H12

Description

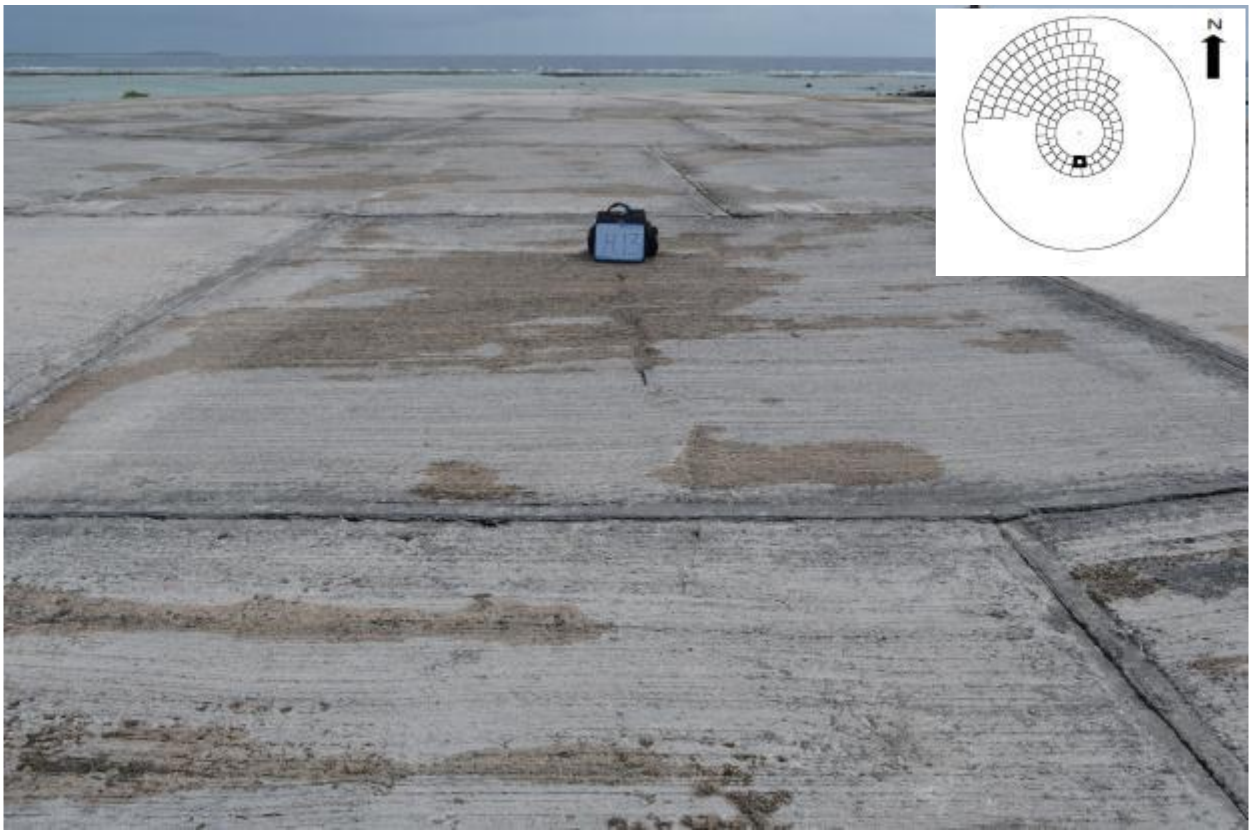
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel H13

Description

No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel H14

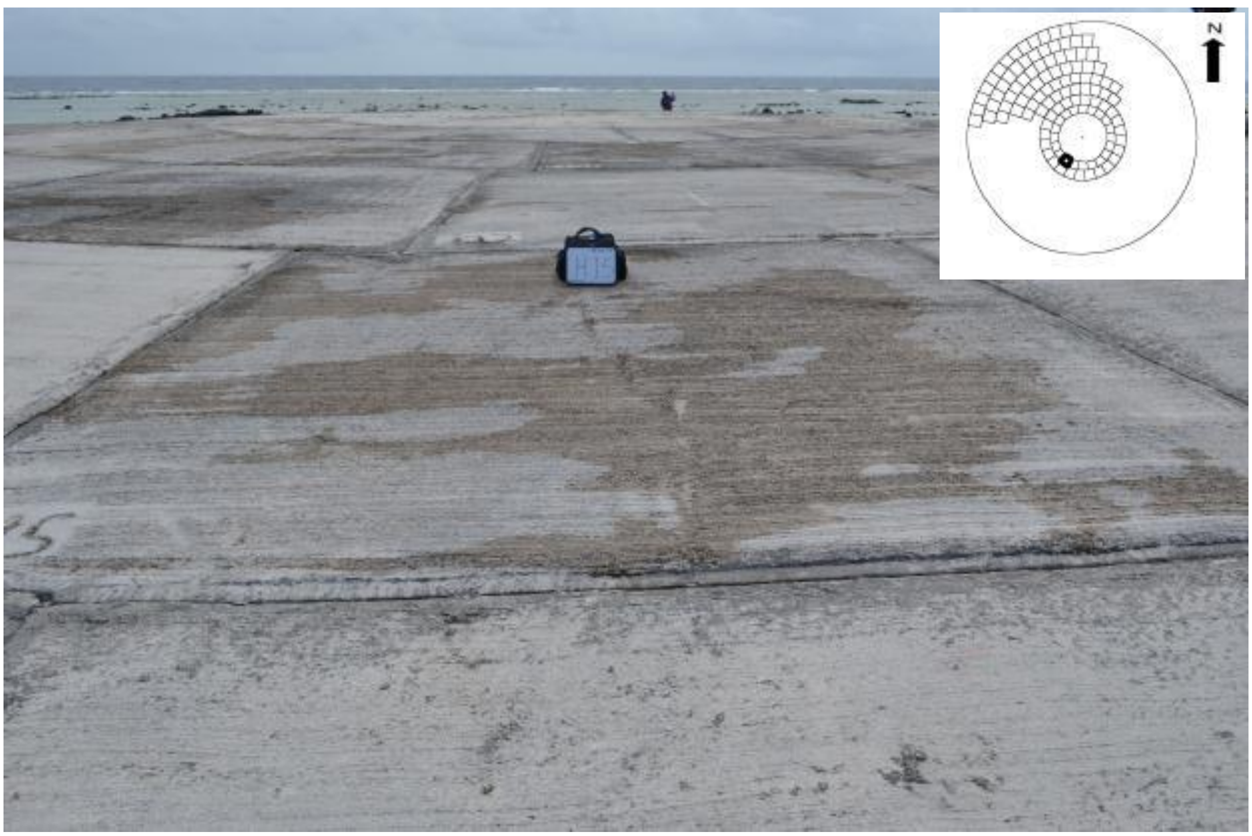
Description

No significant or obvious interior cracks or spall elements. Minor spalling/chipping of concrete in the upper left-hand corner.

CAP SECTION LOCATION: Panel H15

Description

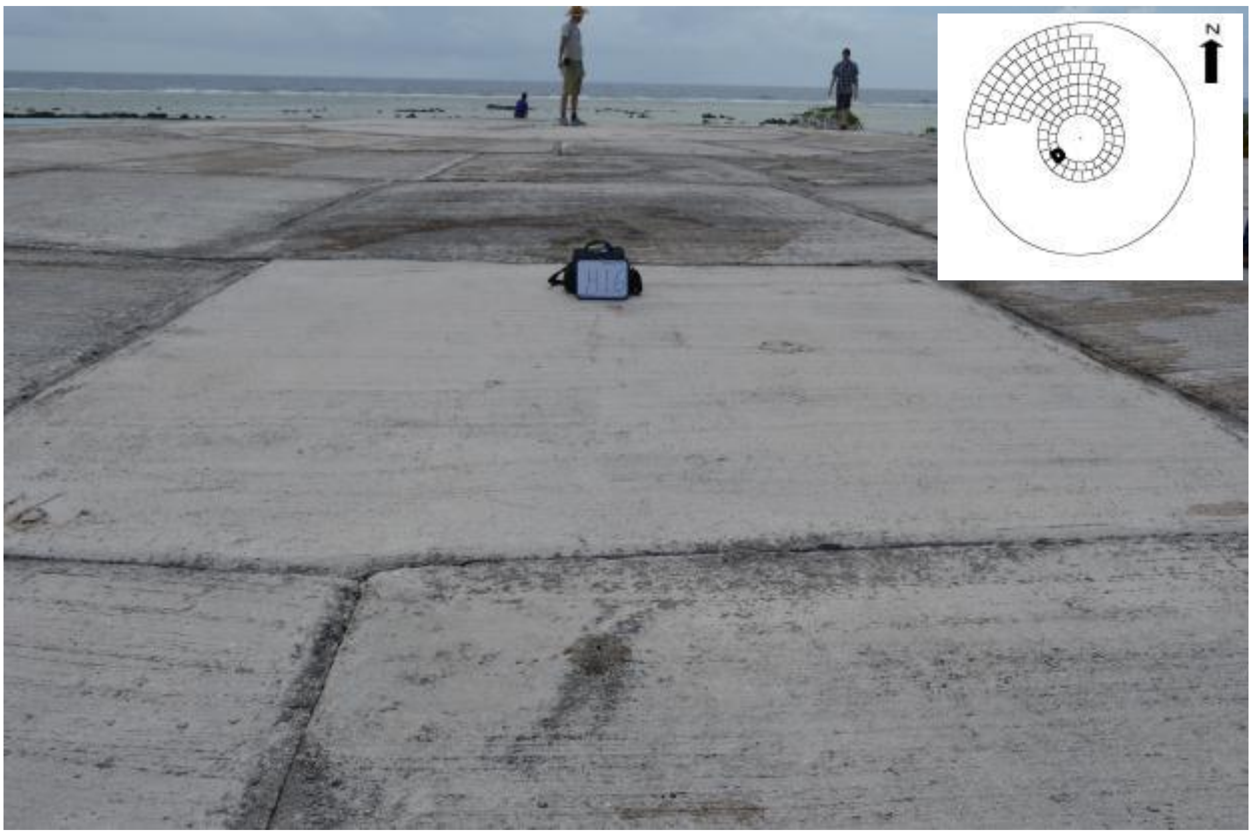
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel H16

Description

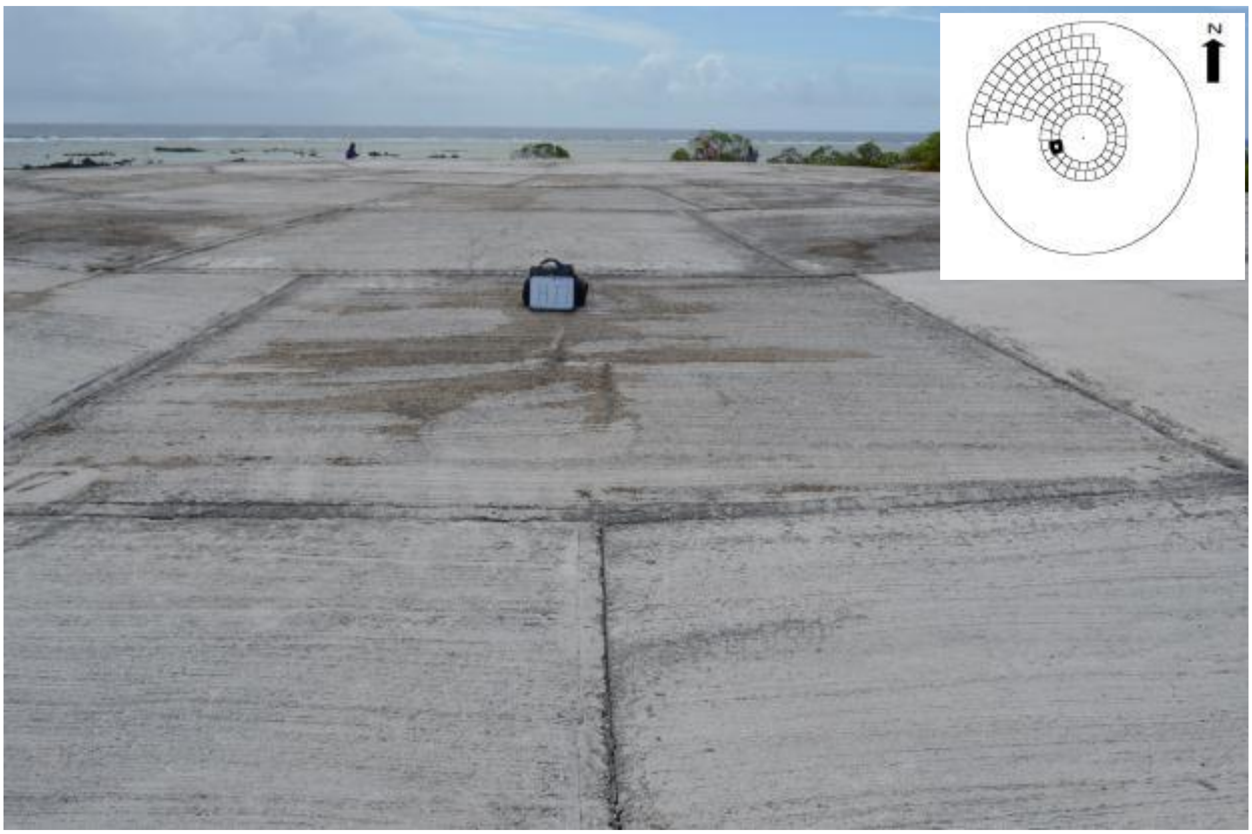
No significant or obvious interior cracks or spall elements identified. Panel contains a filled concrete bore-hole (CD-7) from the 1980 NAS investigation.



CAP SECTION LOCATION: Panel H17

Description

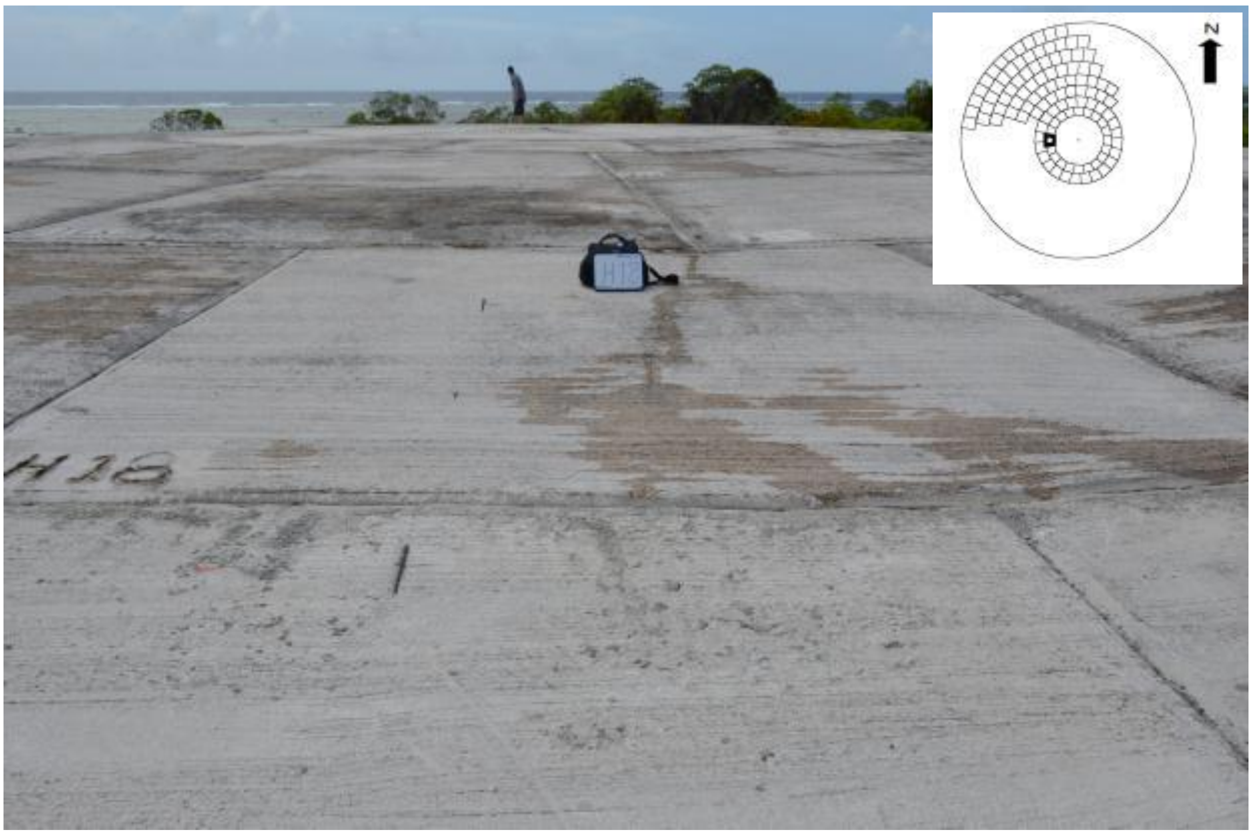
No significant or obvious interior cracks or spall elements identified. Minor spalling/chipping of concrete in the upper right-hand corner.



CAP SECTION LOCATION: Panel H18

Description

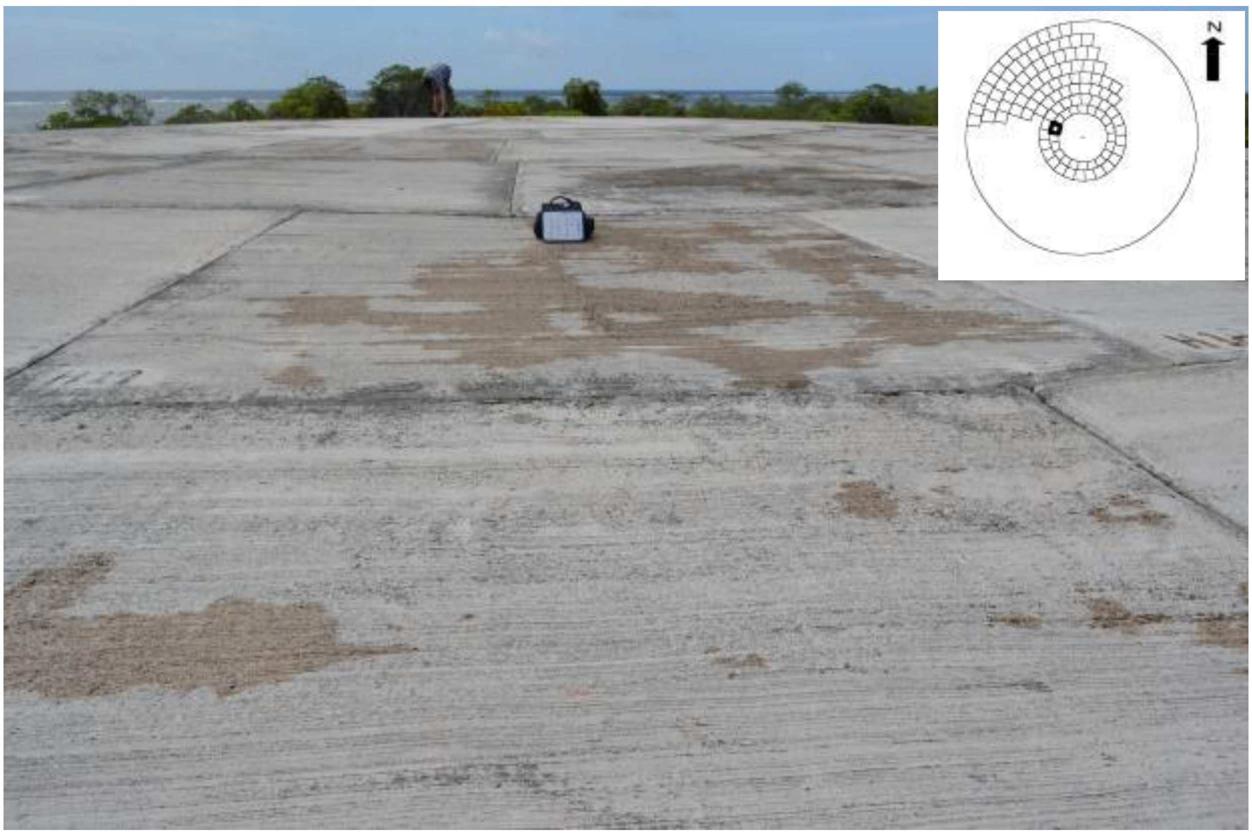
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel H19

Description

No significant or obvious interior cracks or spall elements identified. Minor spalling/chipping of concrete in the top and bottom left-hand corners of the panel.



CAP SECTION LOCATION: Panel H20

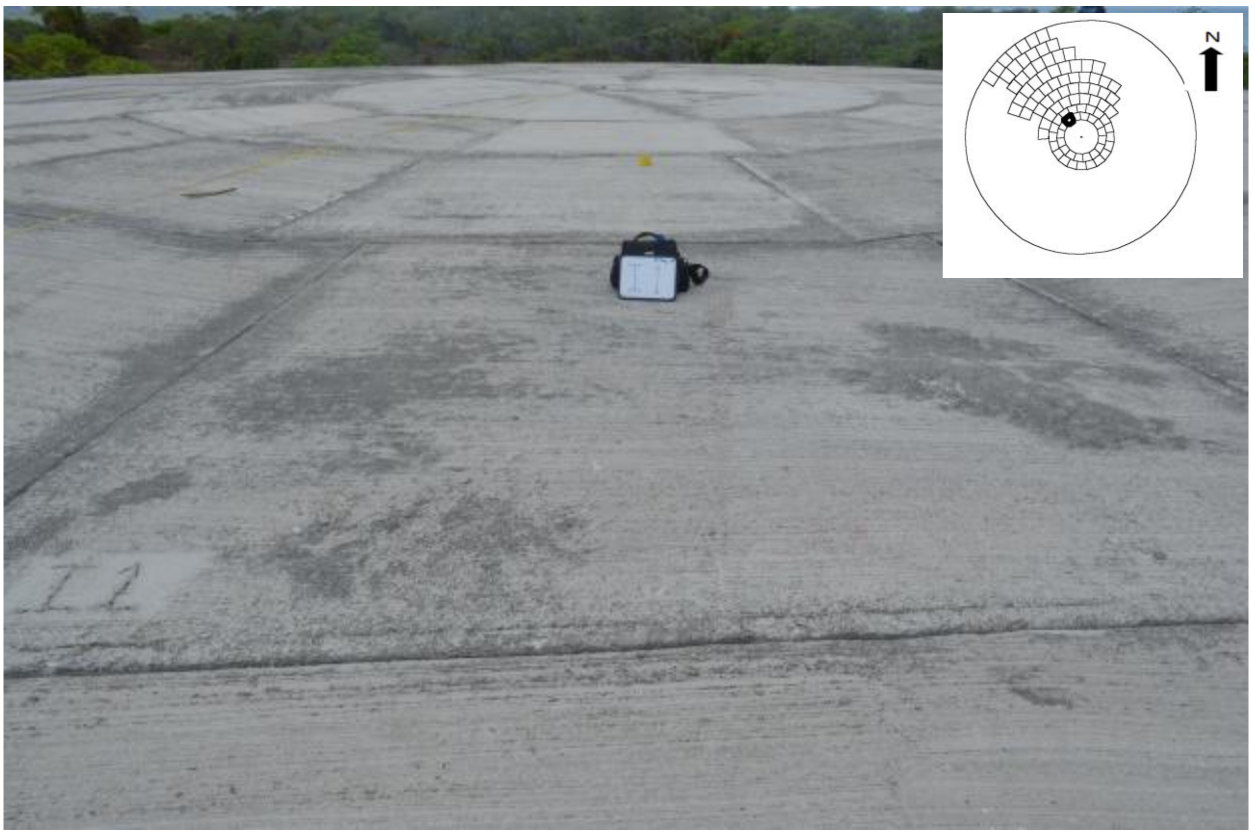
Description

No significant or obvious interior cracks or spall elements identified.

CAP SECTION LOCATION: Panel I1

Description

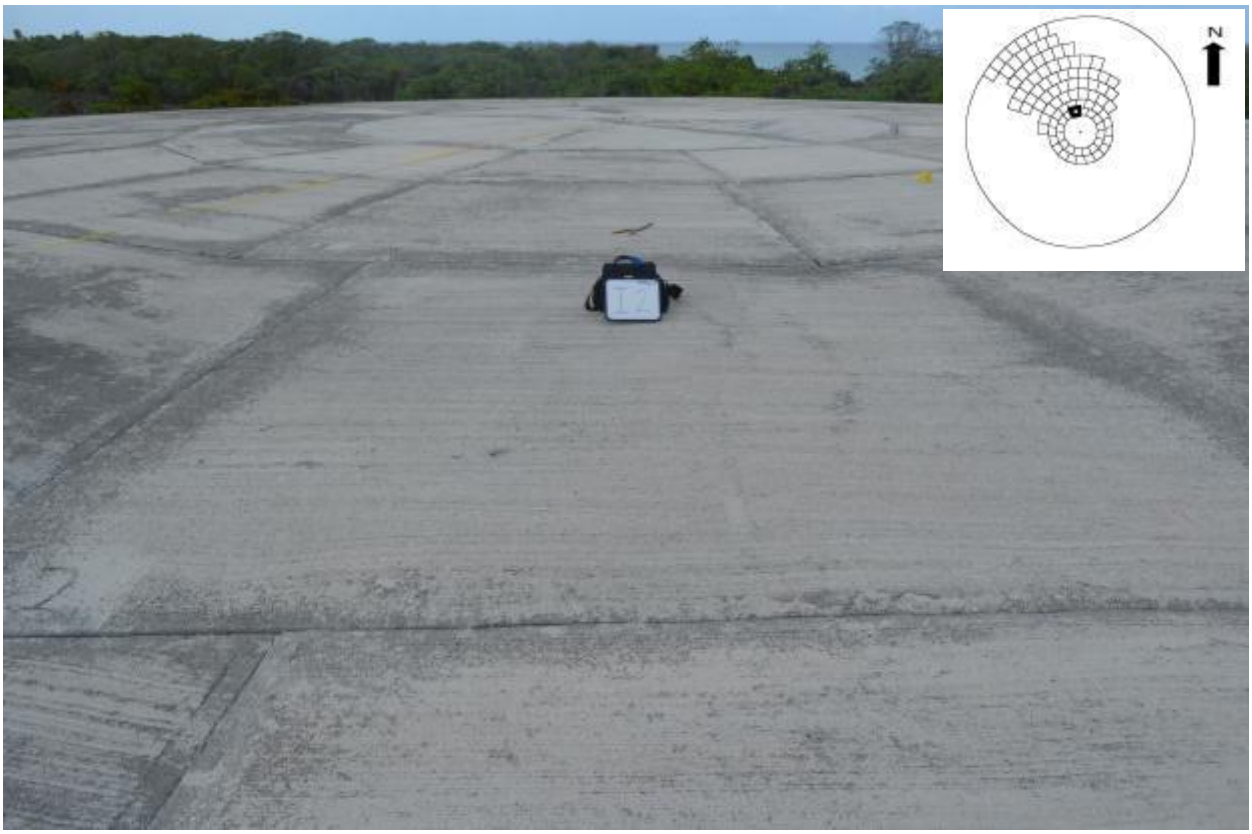
No significant or obvious interior cracks or spall elements identified with exception of very minor spalling/chipping of concrete along the right side of the upper seam or panel joint.



CAP SECTION LOCATION: Panel I2

Description

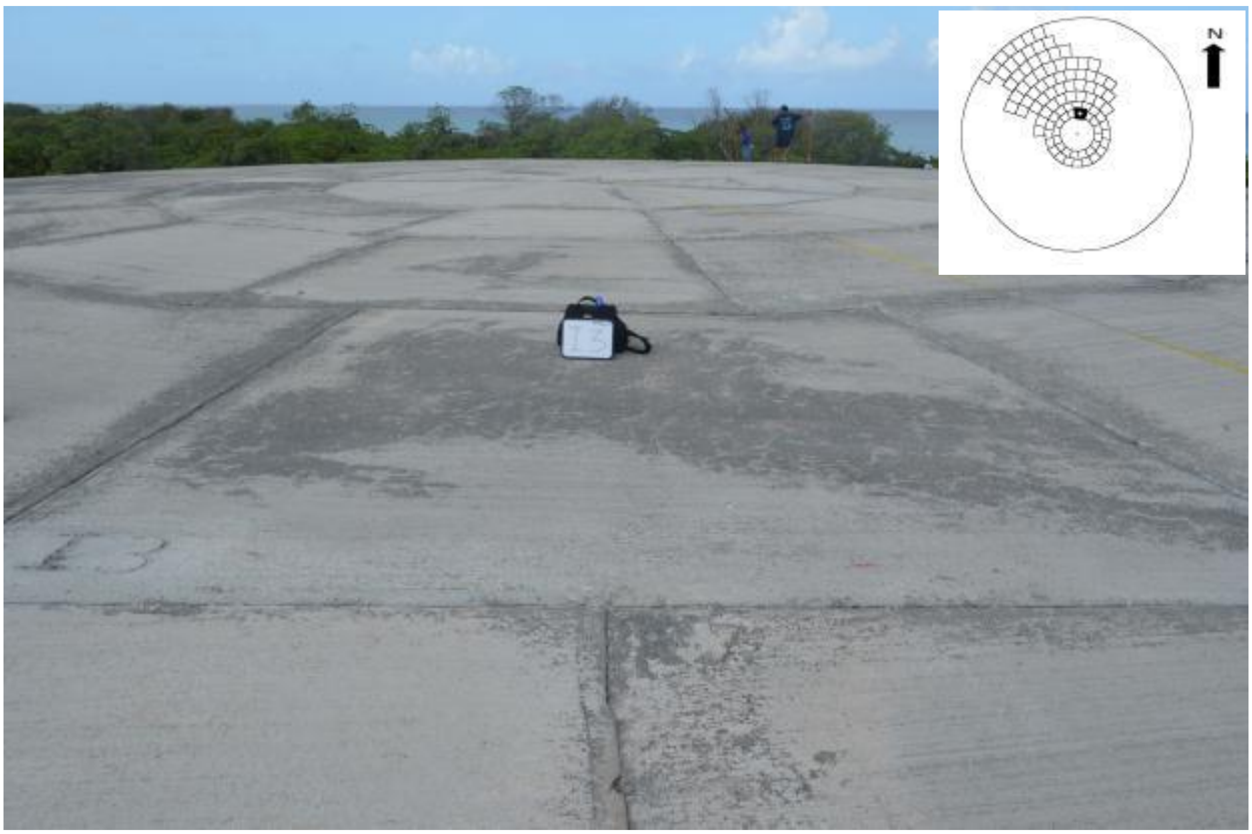
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel I3

Description

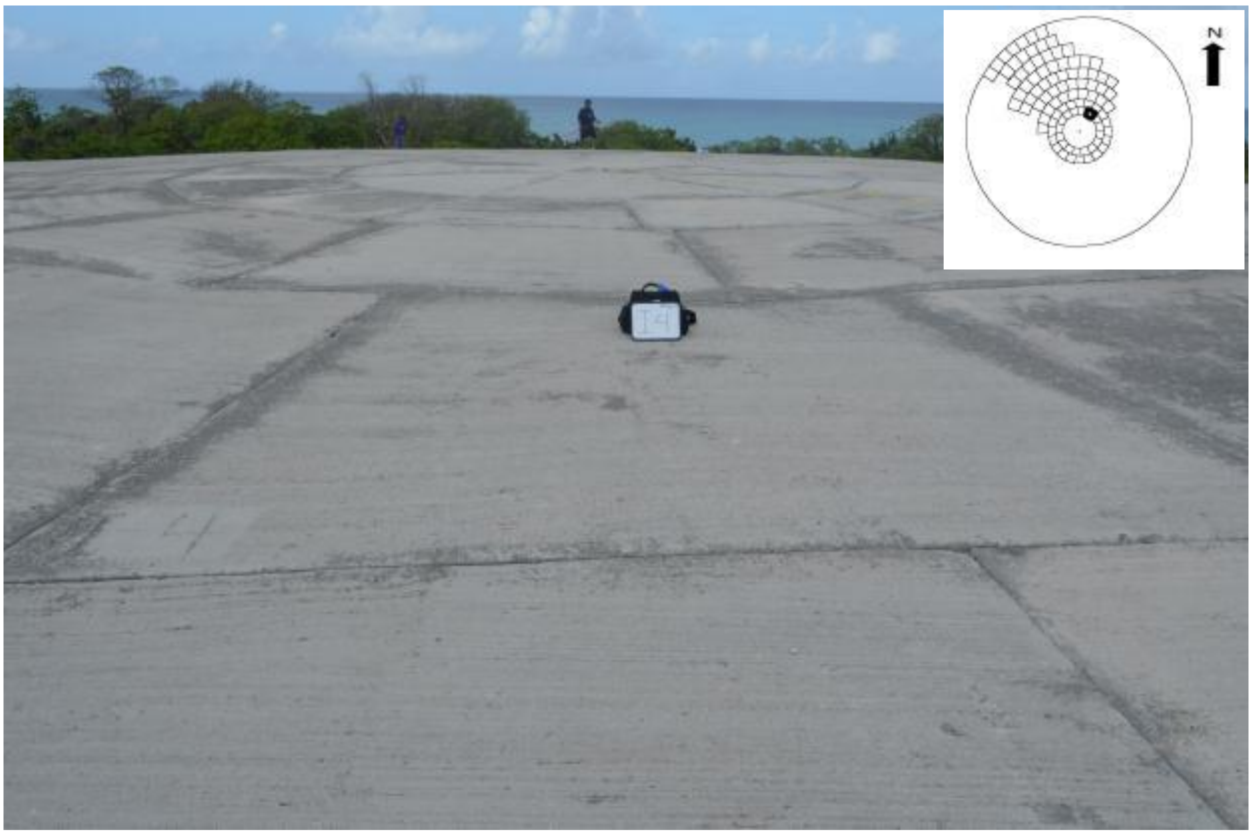
No significant or obvious interior cracks or spall elements identified with exception of spalling/chipping of concrete in the bottom right-hand corner of the panel.



CAP SECTION LOCATION: Panel I4

Description

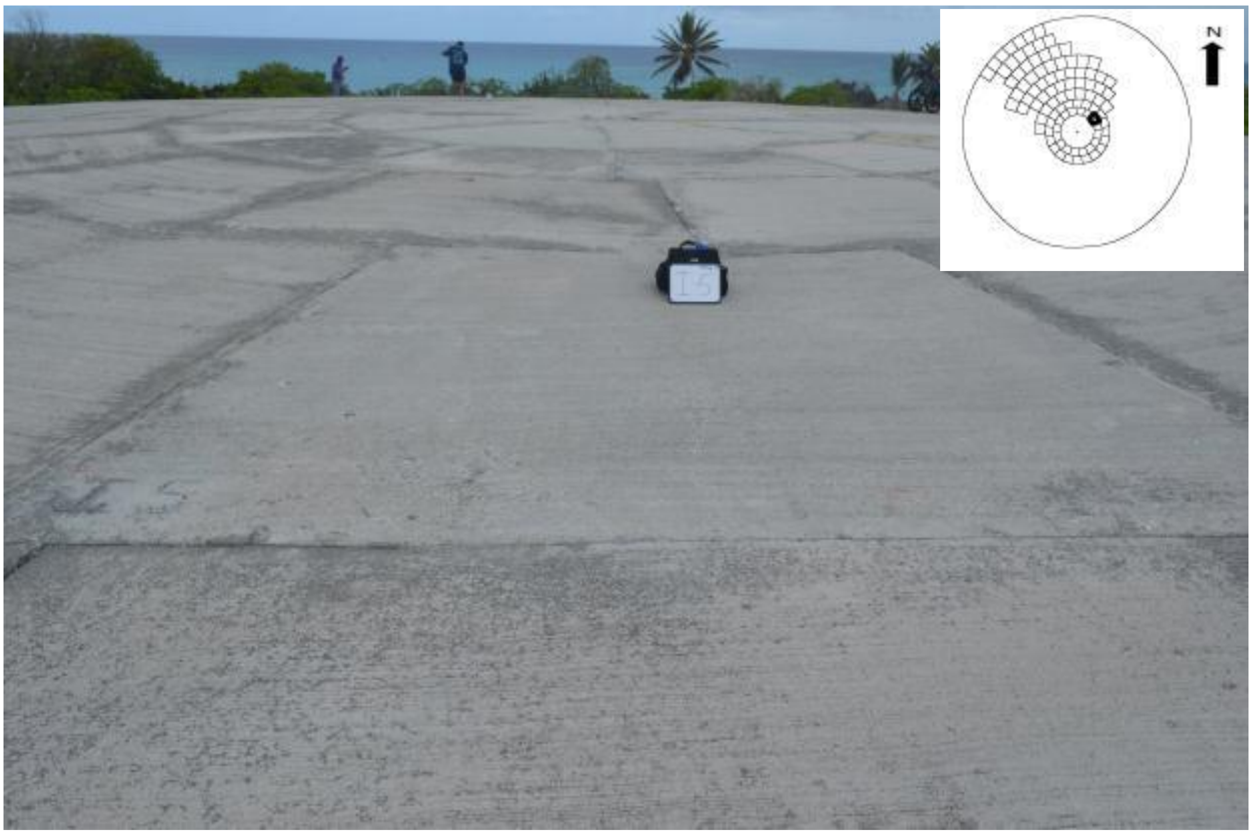
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel I5

Description

No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel I6

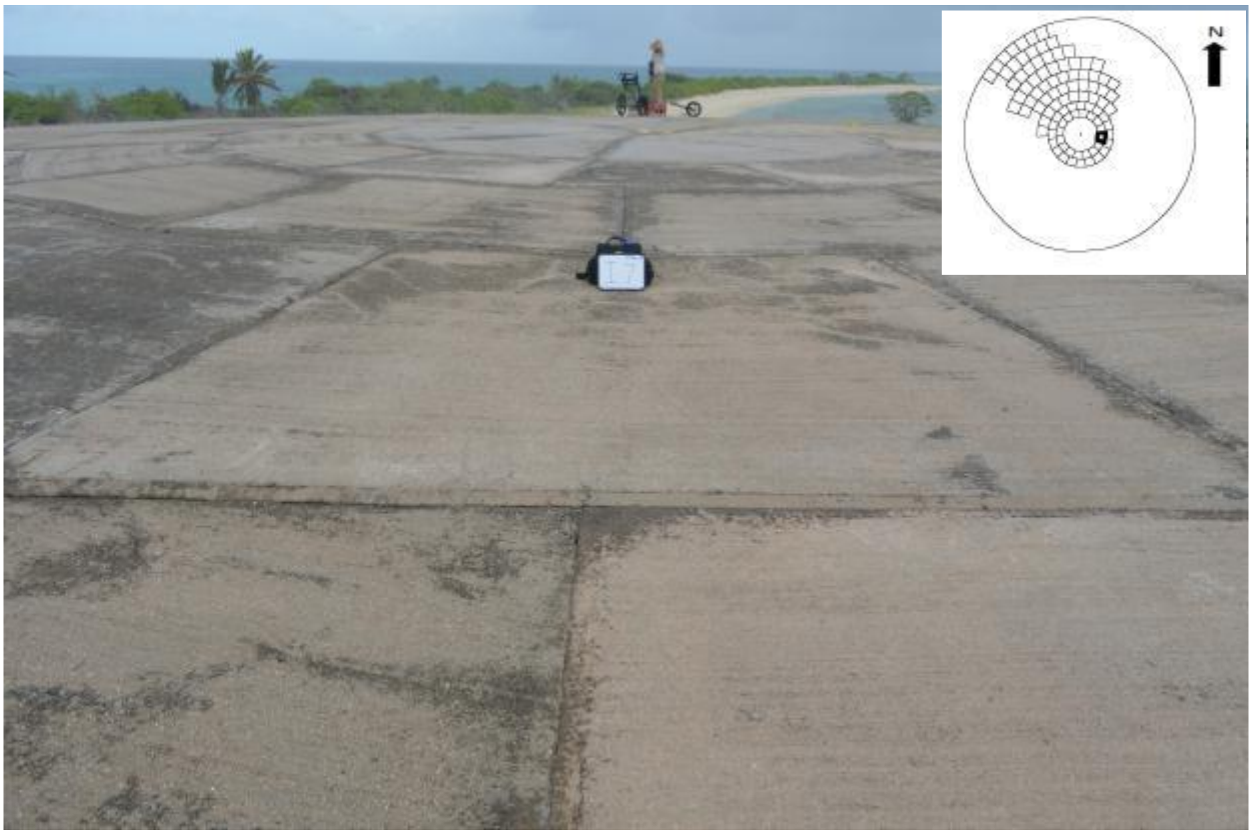
Description

No significant or obvious interior cracks or spall elements identified with exception of very minor spalling/chipping of concrete in the lower left-hand corner of the panel.

CAP SECTION LOCATION: Panel I7

Description

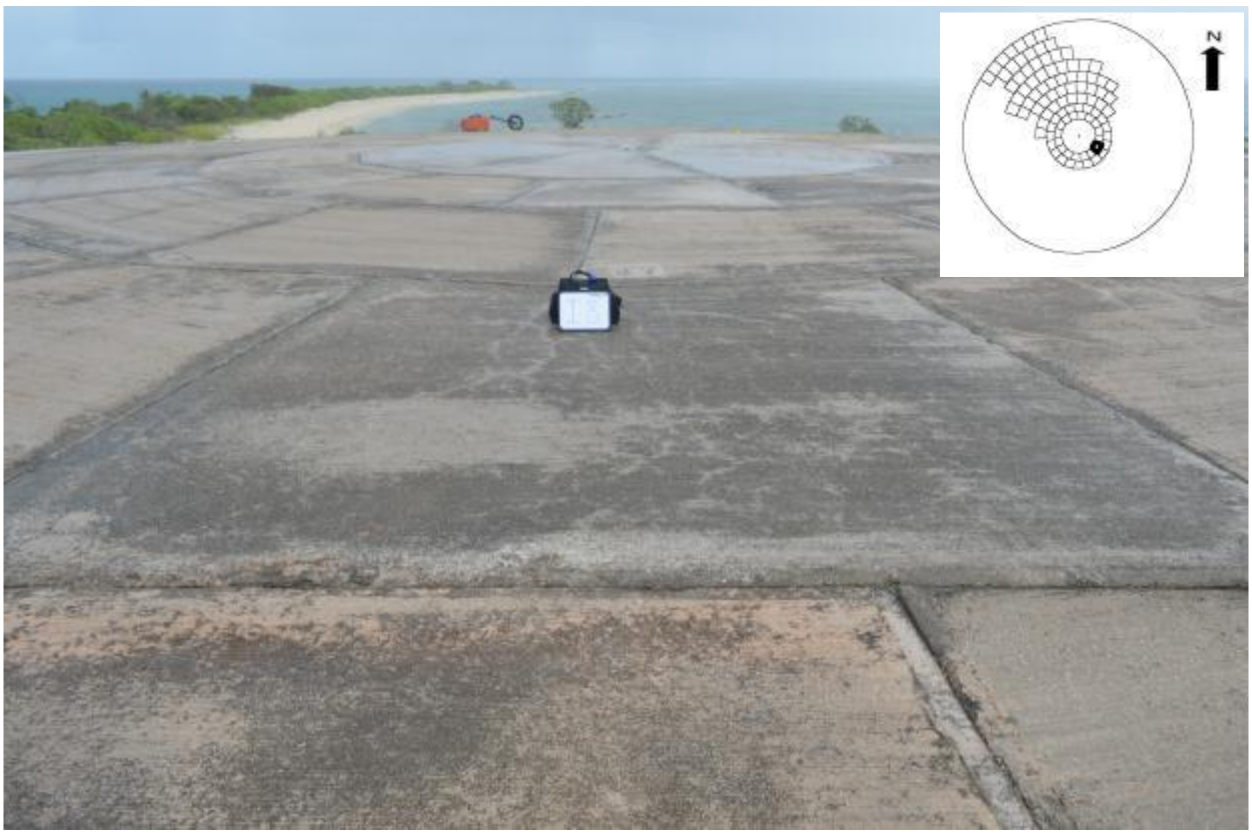
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel I8

Description

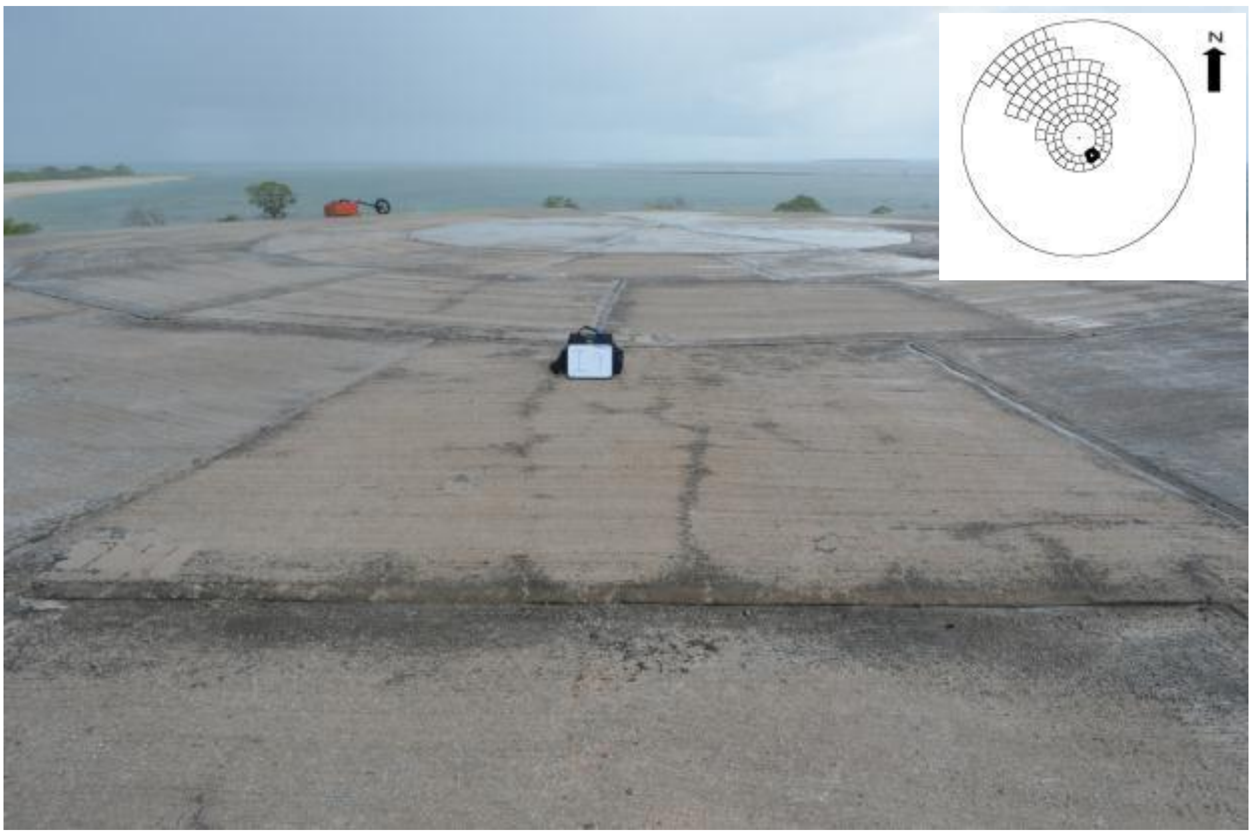
No significant or obvious interior cracks or spall elements identified with exception of very minor spalling/chipping of concrete in the bottom left-hand corner of the panel.



CAP SECTION LOCATION: Panel I9

Description

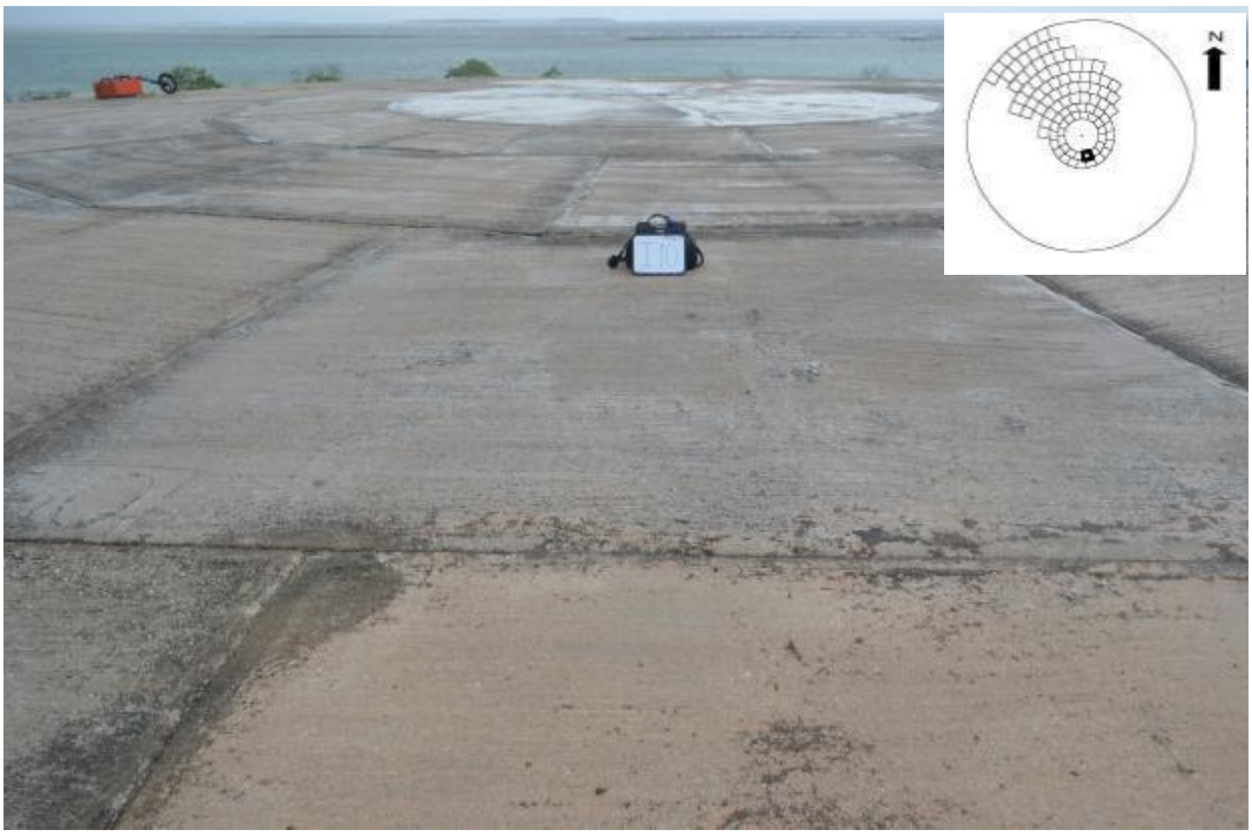
No significant or obvious interior cracks or spall elements identified with exception of spalling/chipping of concrete in the bottom left-hand corner of the panel.



CAP SECTION LOCATION: Panel I10

Description

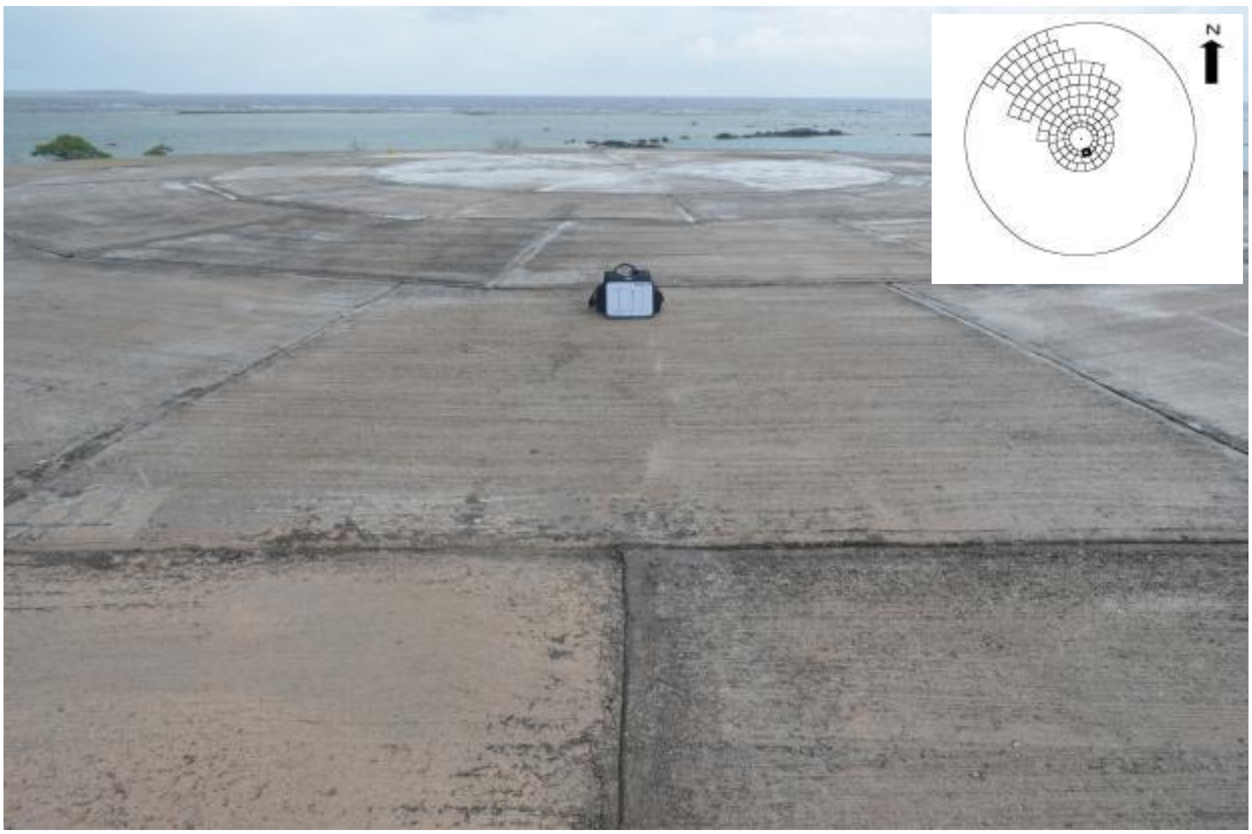
No significant or obvious interior cracks or spall elements identified with exception of spalling/chipping of concrete in the bottom left-hand corner of the panel.



CAP SECTION LOCATION: Panel I11

Description

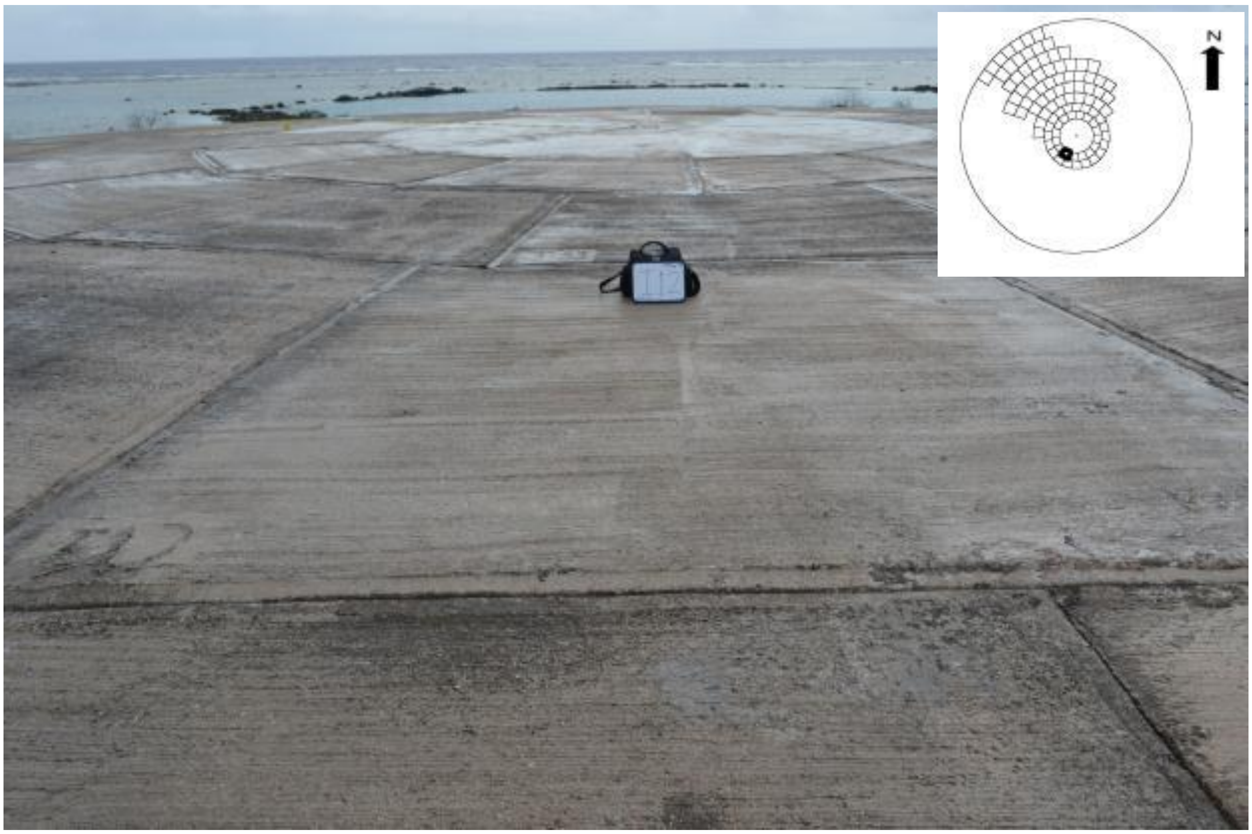
No significant or obvious interior cracks or spall elements identified with exception of minor spalling/chipping of concrete in the bottom left-hand corner of the panel.



CAP SECTION LOCATION: Panel I12

Description

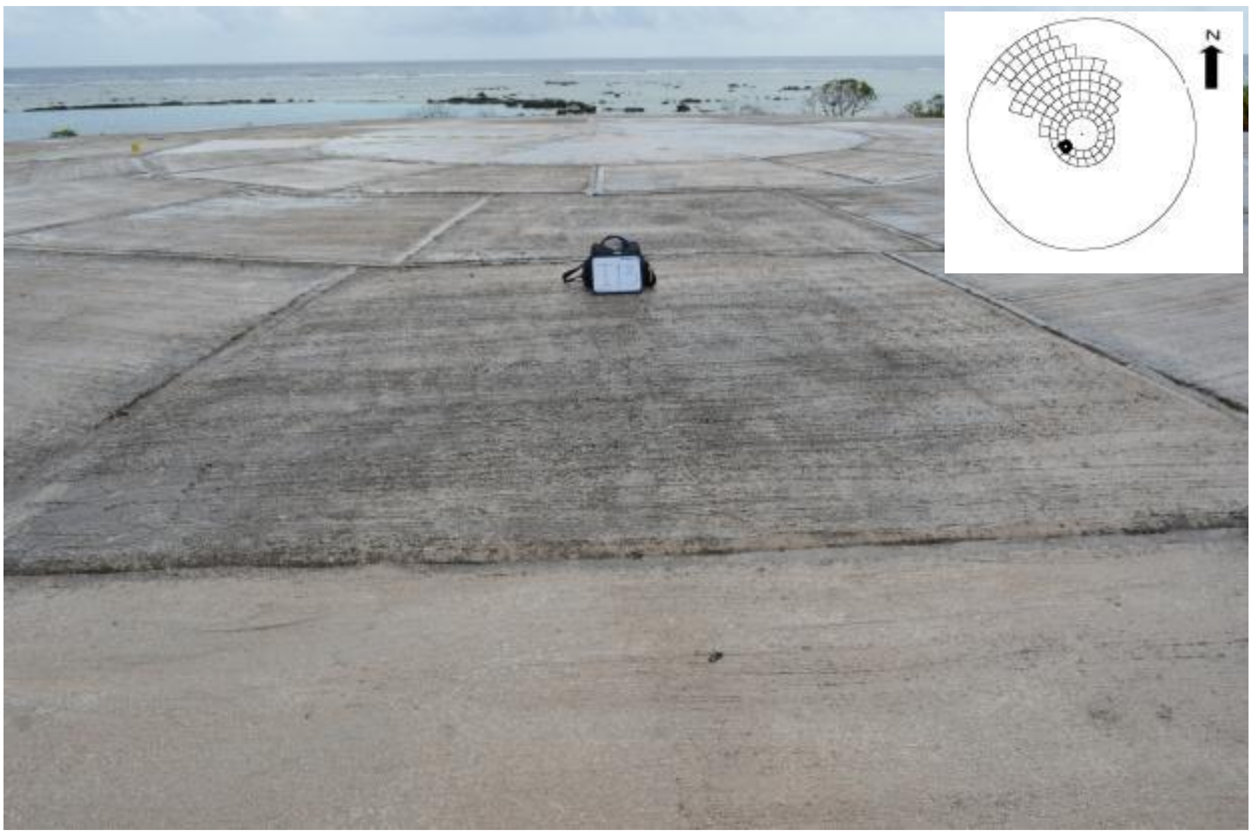
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel I13

Description

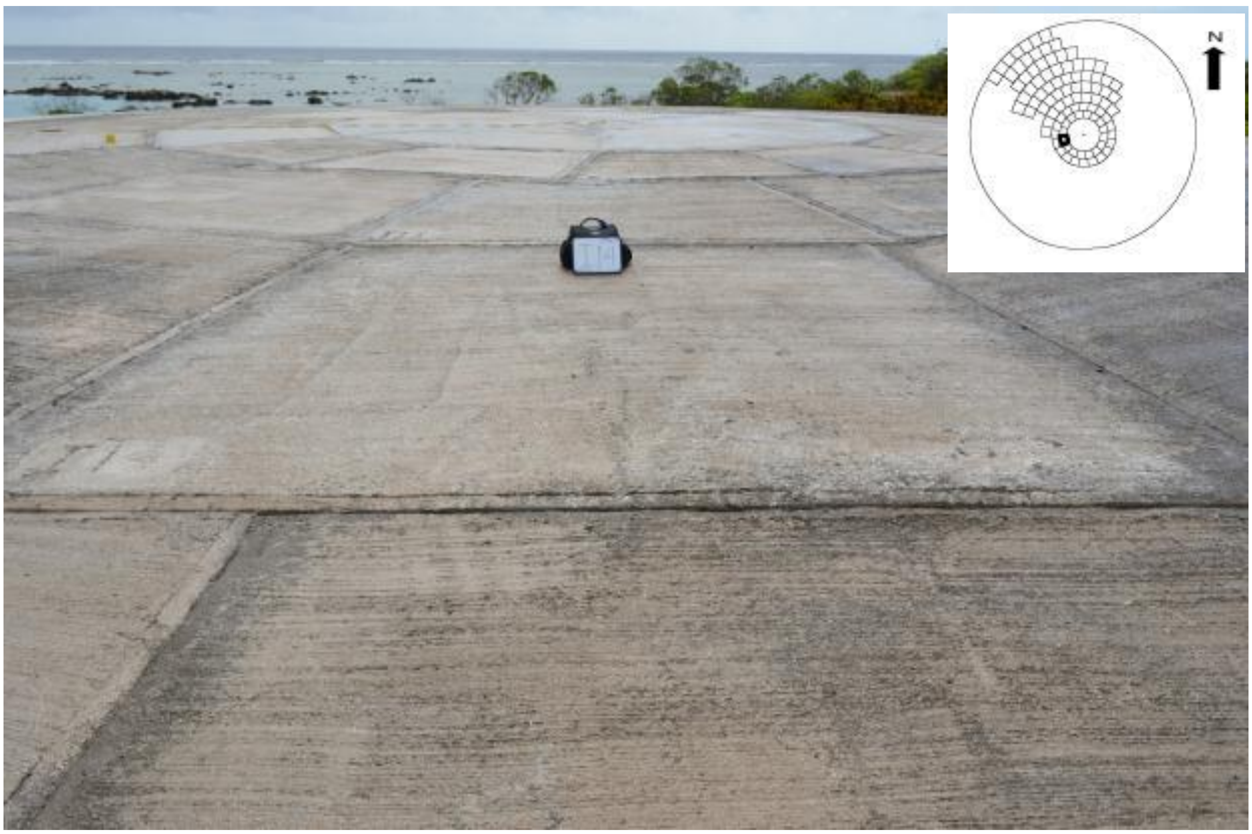
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel I14

Description

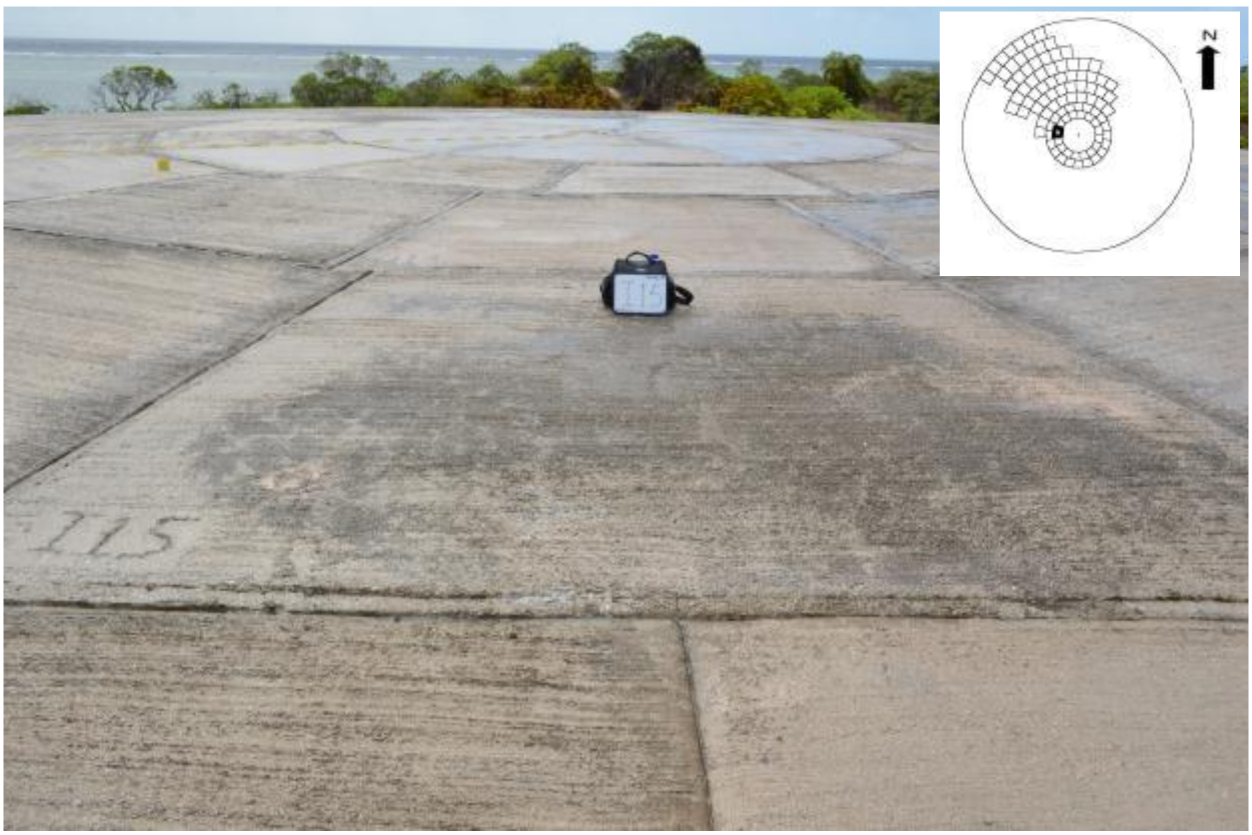
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel I15

Description

No significant or obvious interior cracks or spall elements identified with exception of spalling/chipping of concrete in the left-hand corner of the panel. Panel contains a filled concrete bore-hole (CD-8) from the 1980 NAS investigation.



CAP SECTION LOCATION: Panel I16

Description

No significant or obvious interior cracks or spall elements identified with exception of minor spalling/chipping of concrete in the left-hand corner of the panel.

CAP SECTION LOCATION: Panel J1

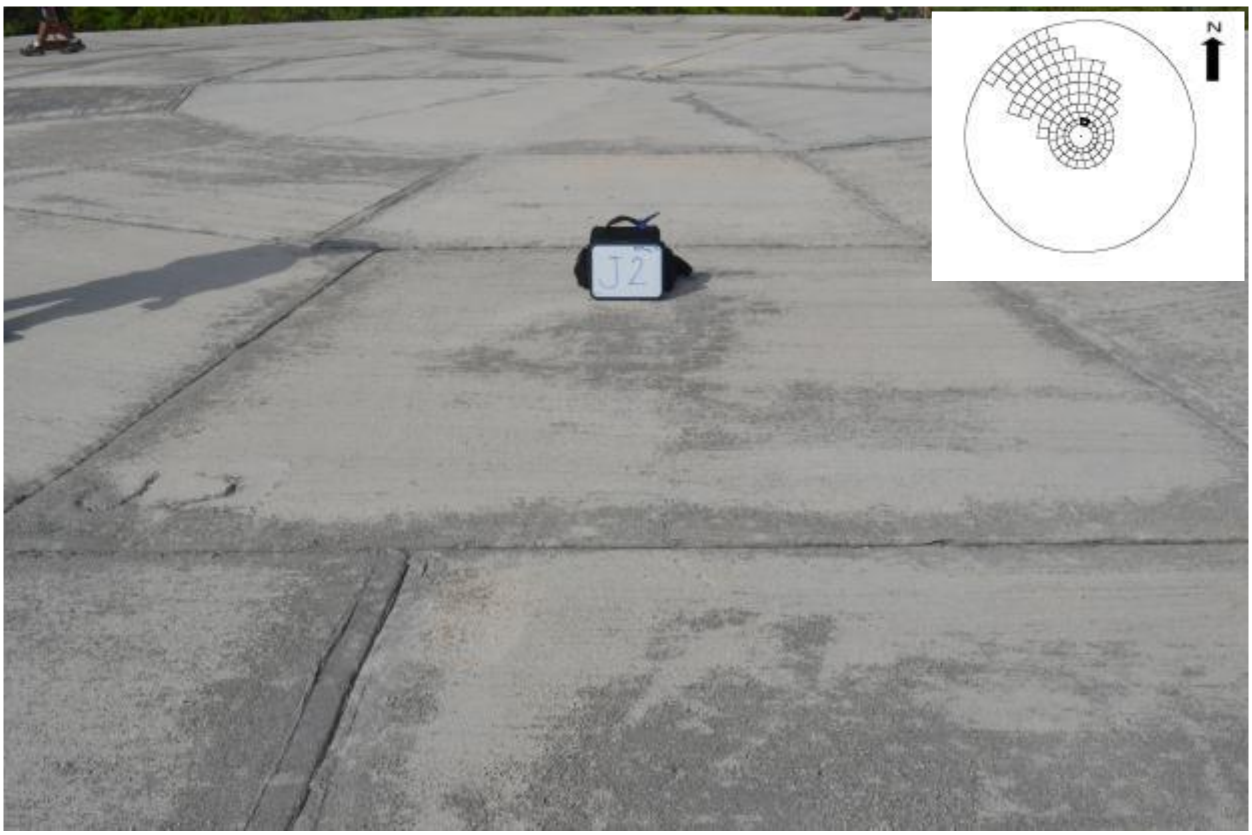
Description

No significant or obvious interior cracks or spall elements identified.

CAP SECTION LOCATION: Panel J2

Description

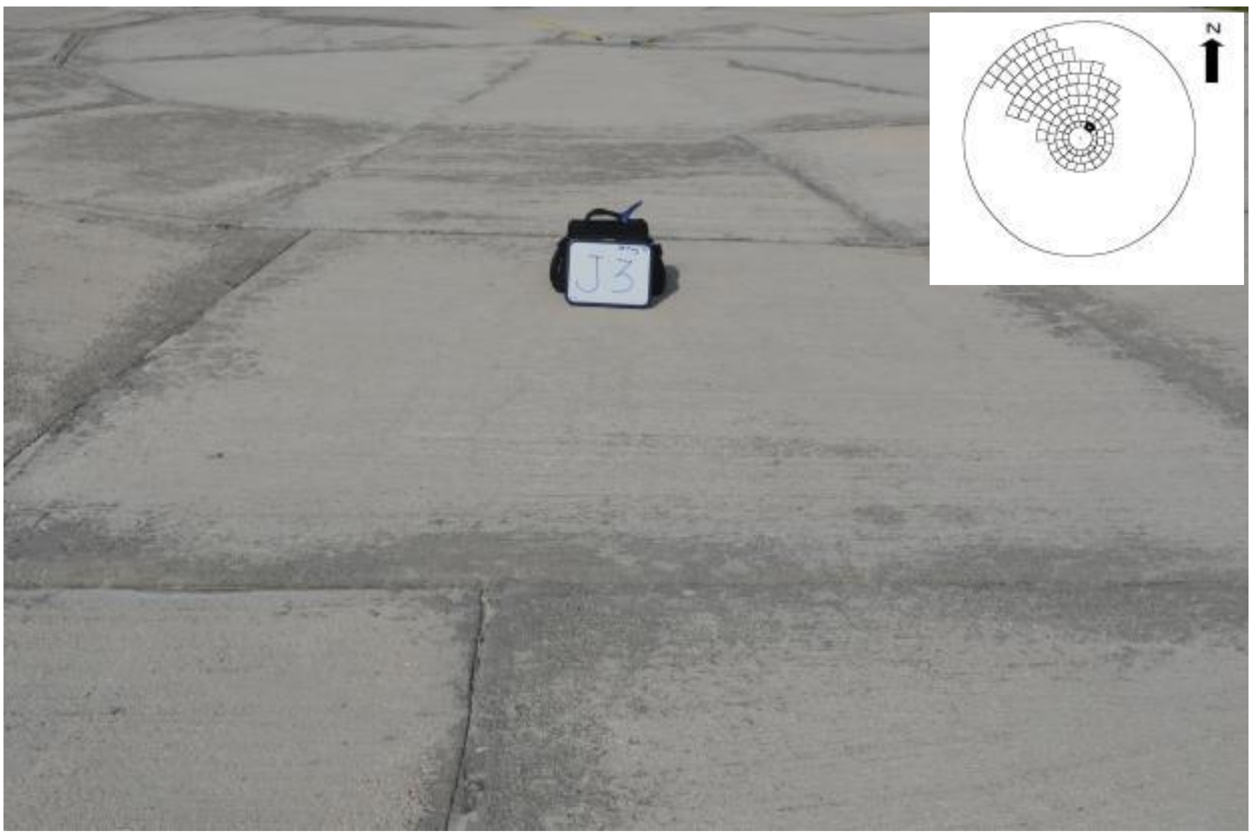
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel J3

Description

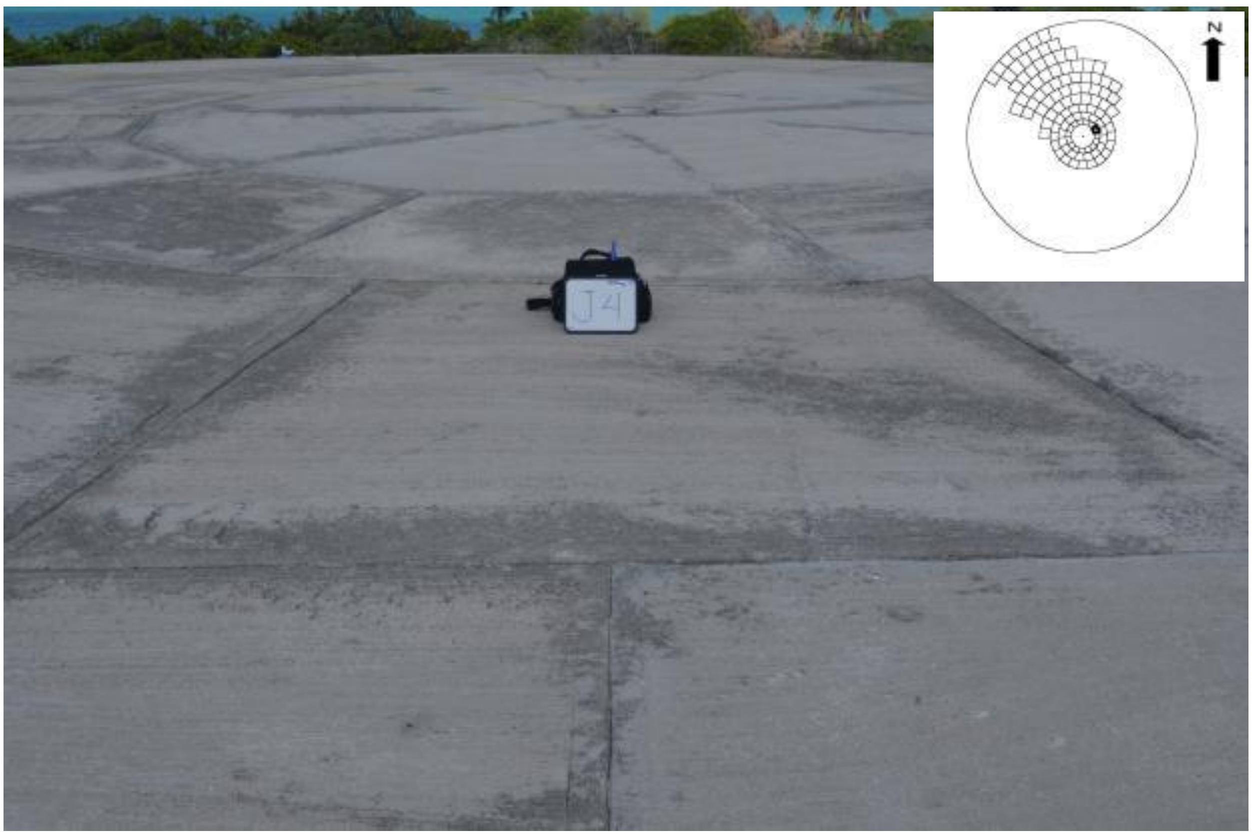
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel J4

Description

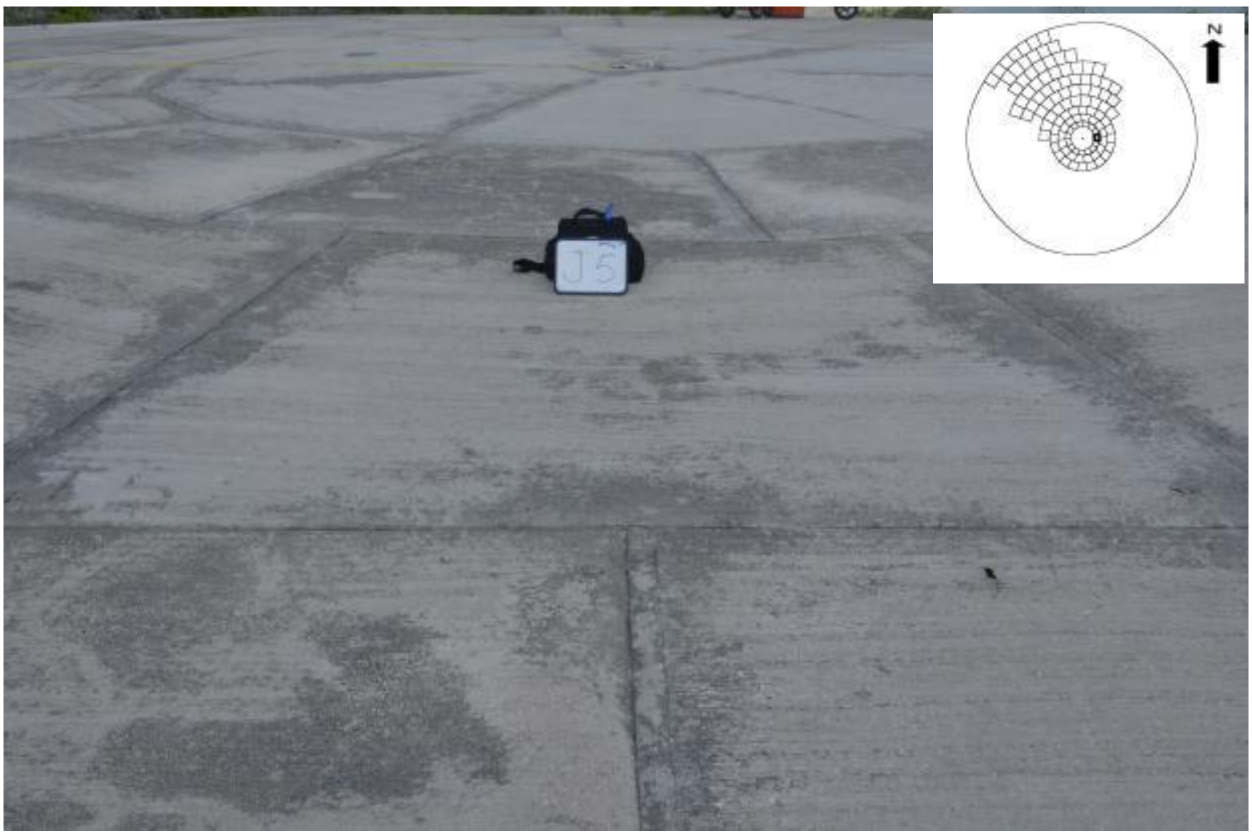
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel J5

Description

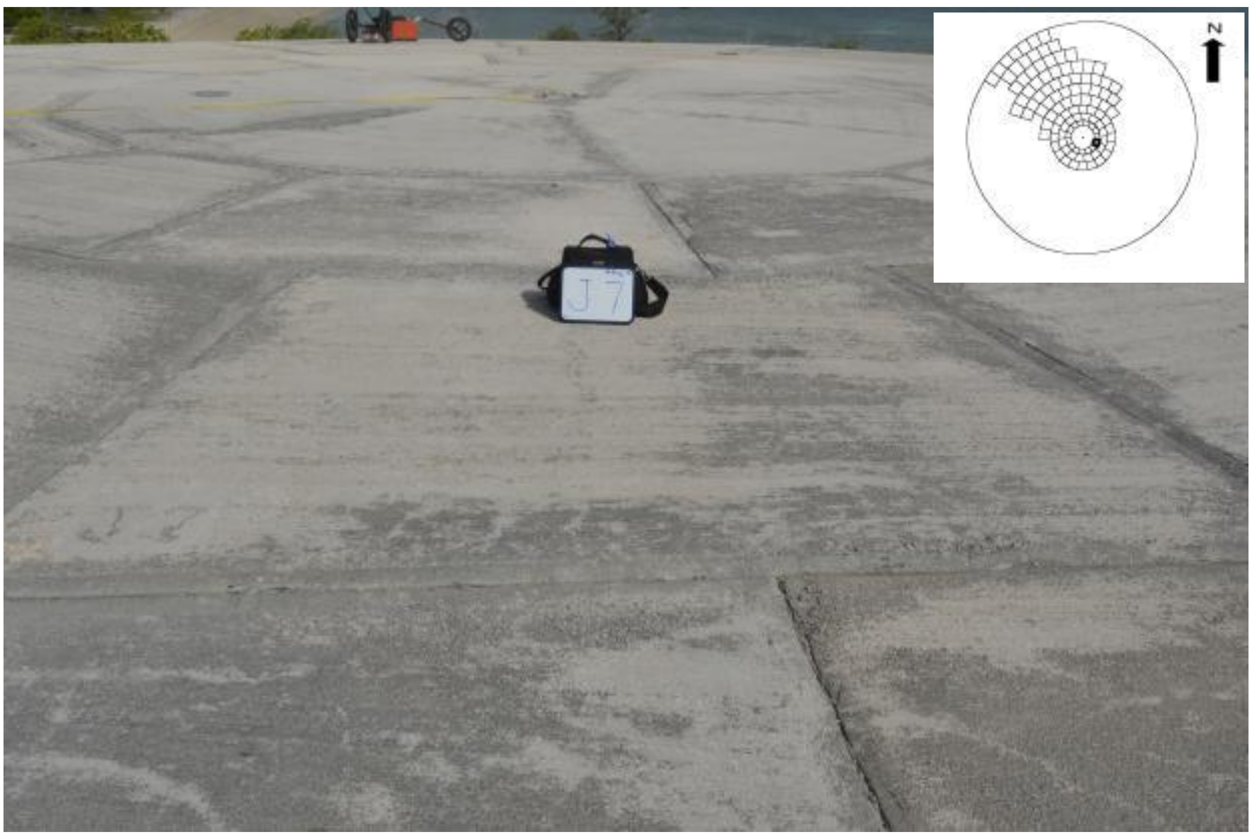
No significant or obvious interior cracks or spall elements identified (no J6 panel present).



CAP SECTION LOCATION: Panel J7

Description

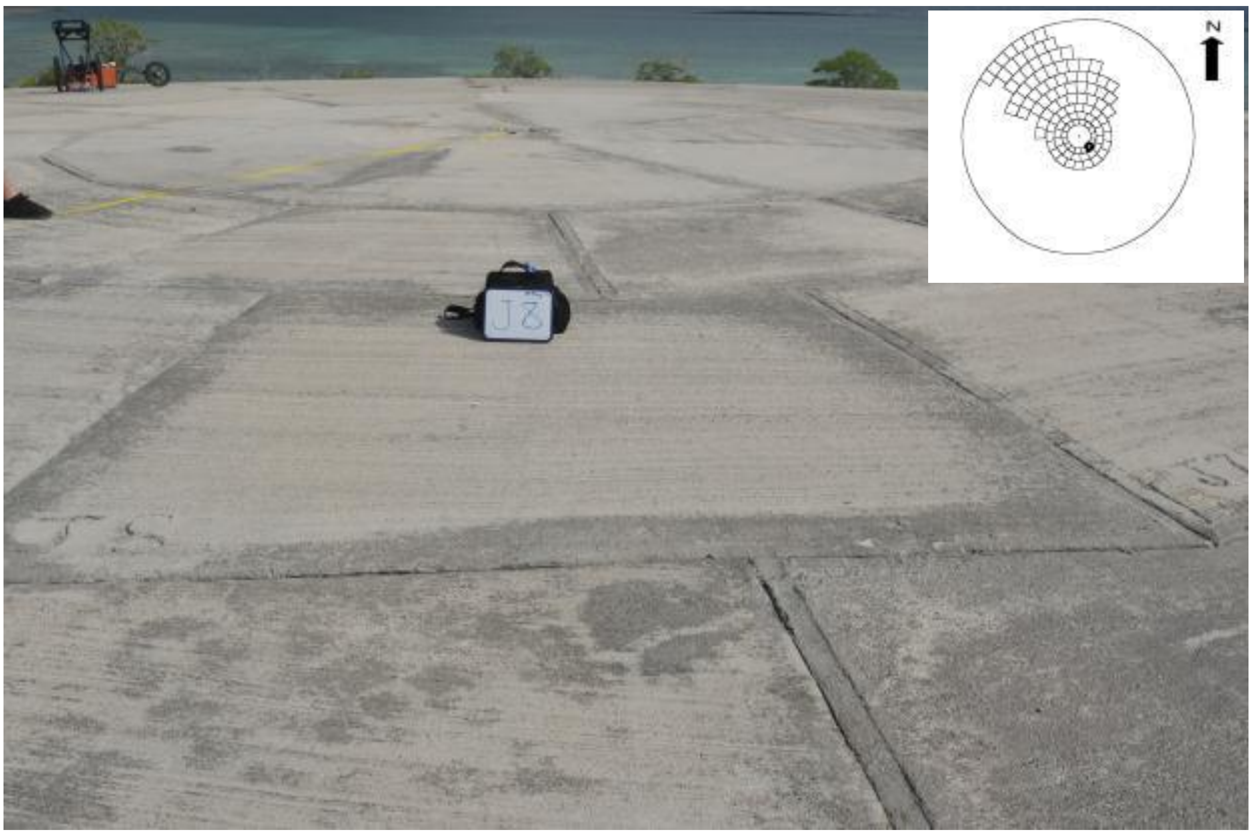
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel J8

Description

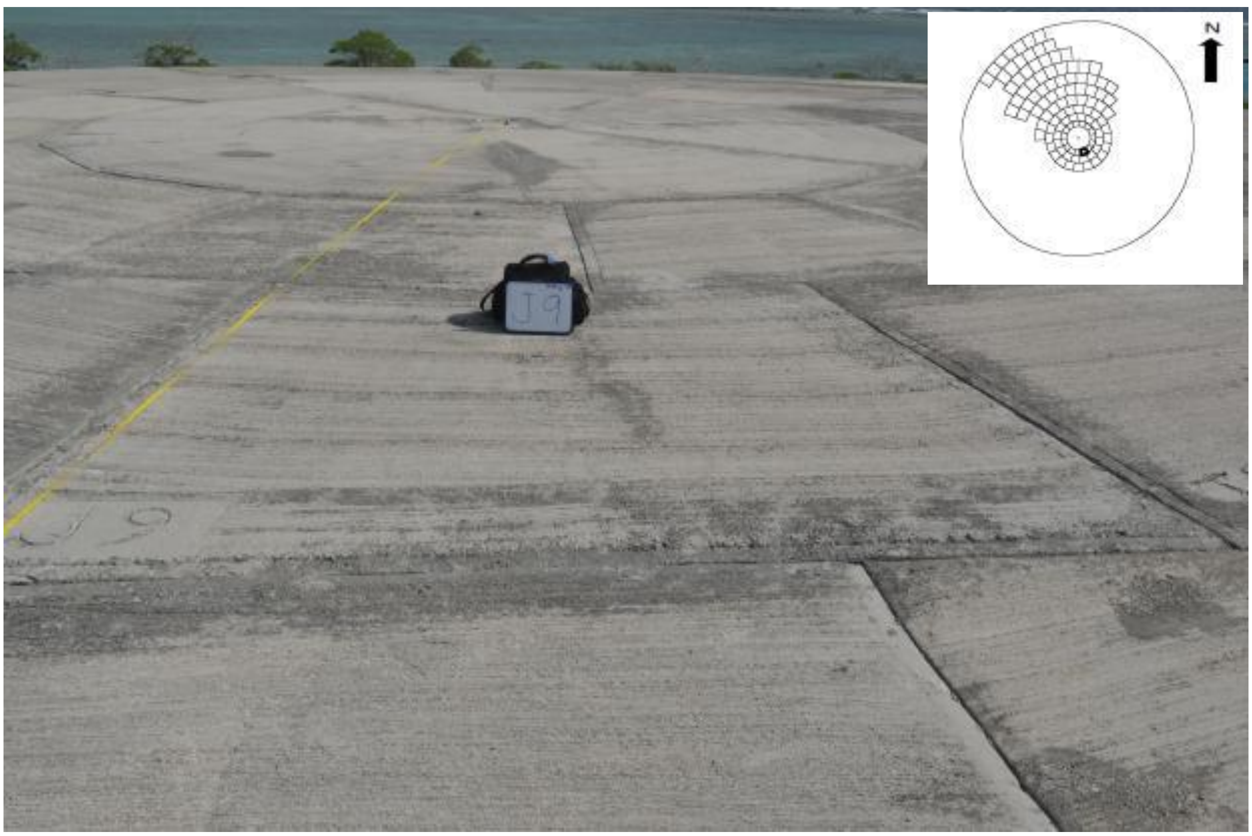
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel J9

Description

No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel J10

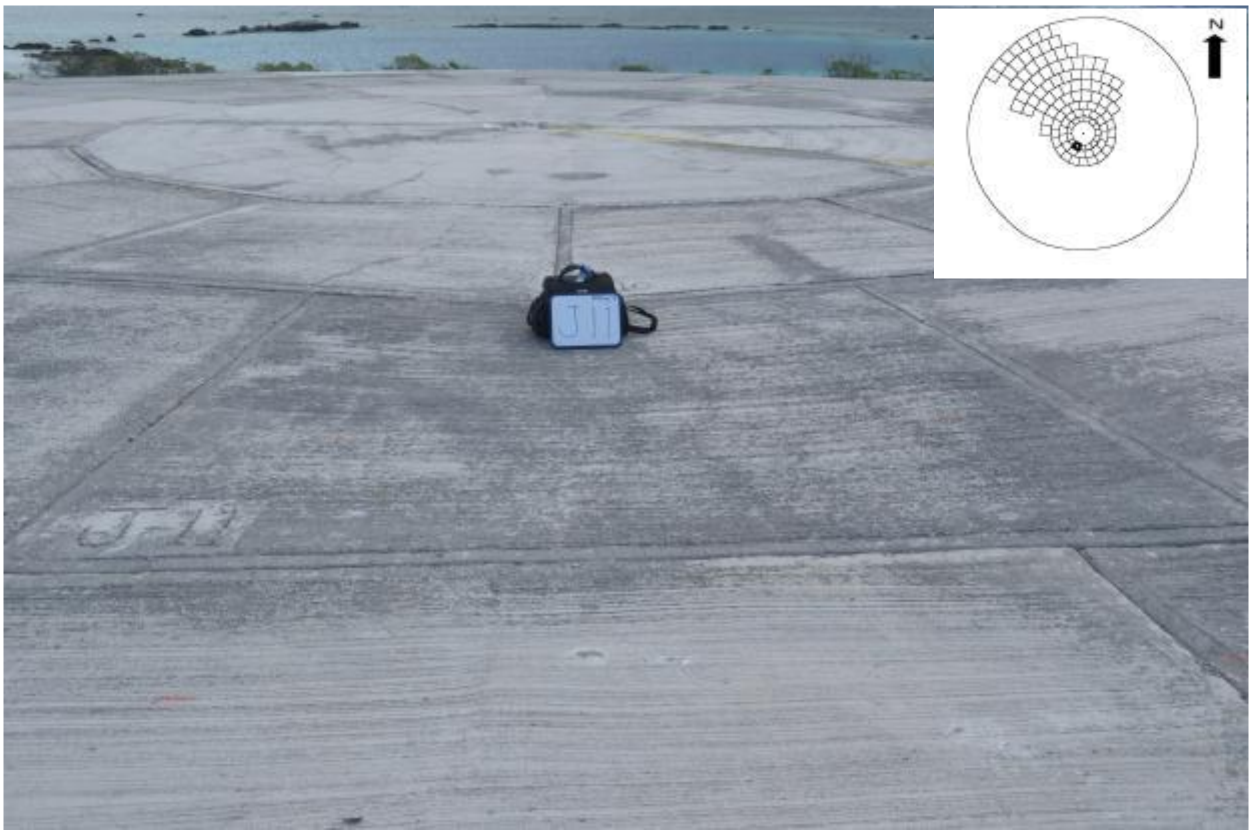
Description

Minor surface crack originating from the intersecting panel corners on the ring row below and traversing up and across the panel towards the upper right-hand corner.

CAP SECTION LOCATION: Panel J11

Description

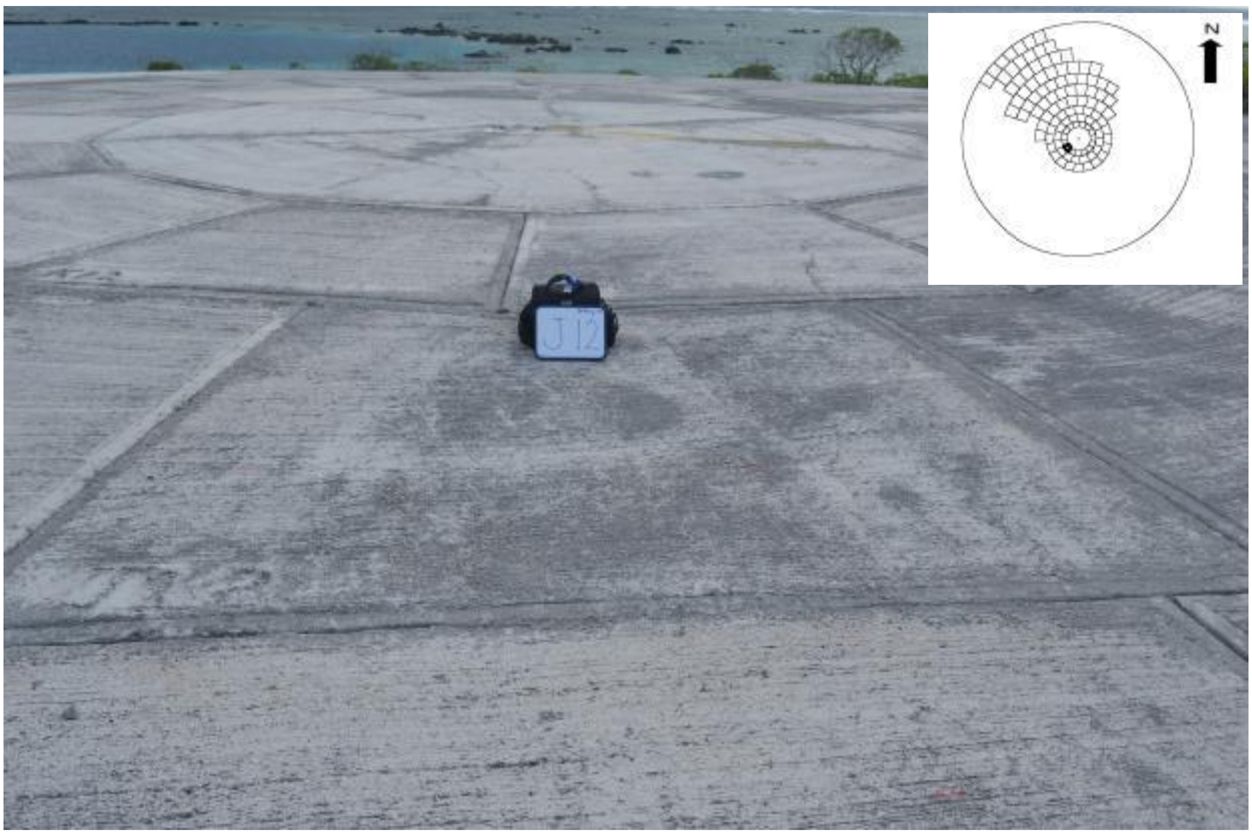
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel J12

Description

No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel J13

Description

No significant or obvious interior cracks or spall elements identified.

CAP SECTION LOCATION: Panel J14

Description

No significant or obvious interior cracks or spall elements identified.

CAP SECTION LOCATION: Panel J15

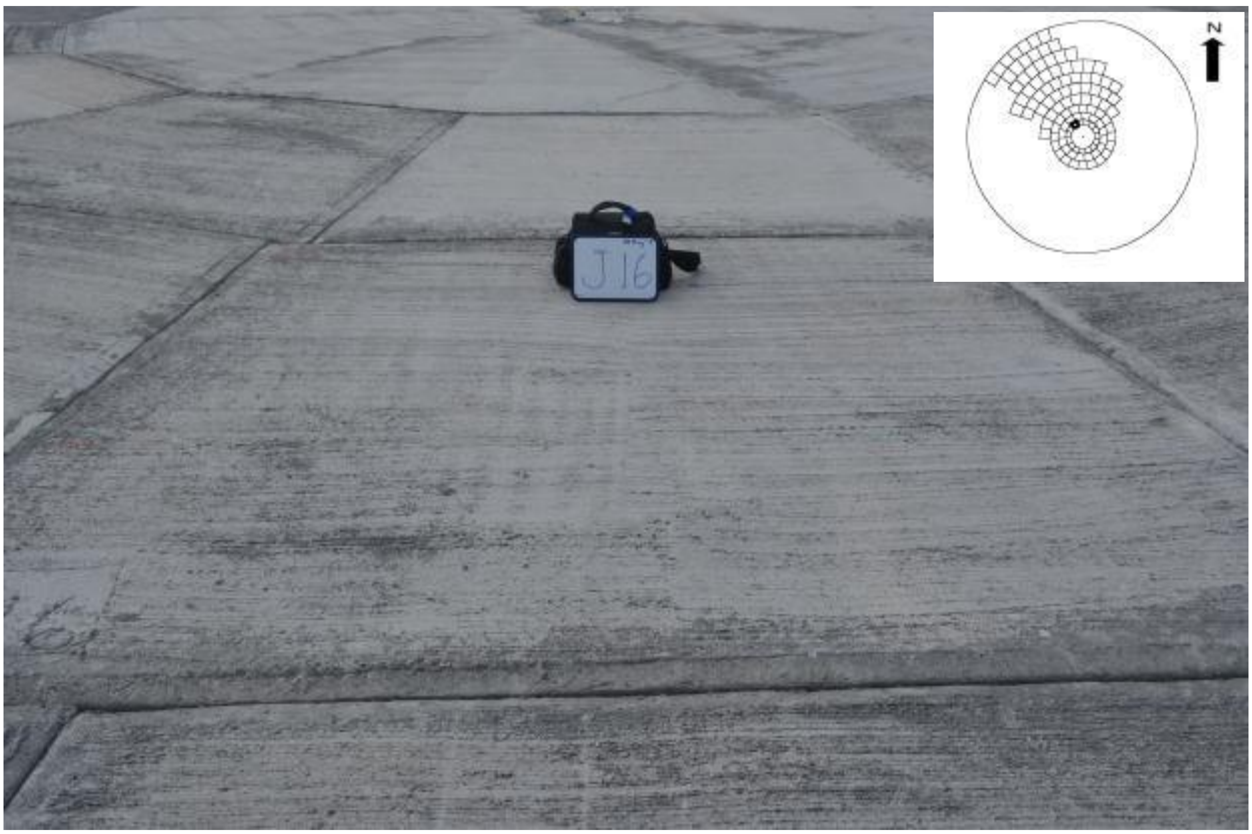
Description

No significant or obvious interior cracks or spall elements identified with exception of very minor spalling of concrete along the left side of the upper seam.

CAP SECTION LOCATION: Panel J16

Description

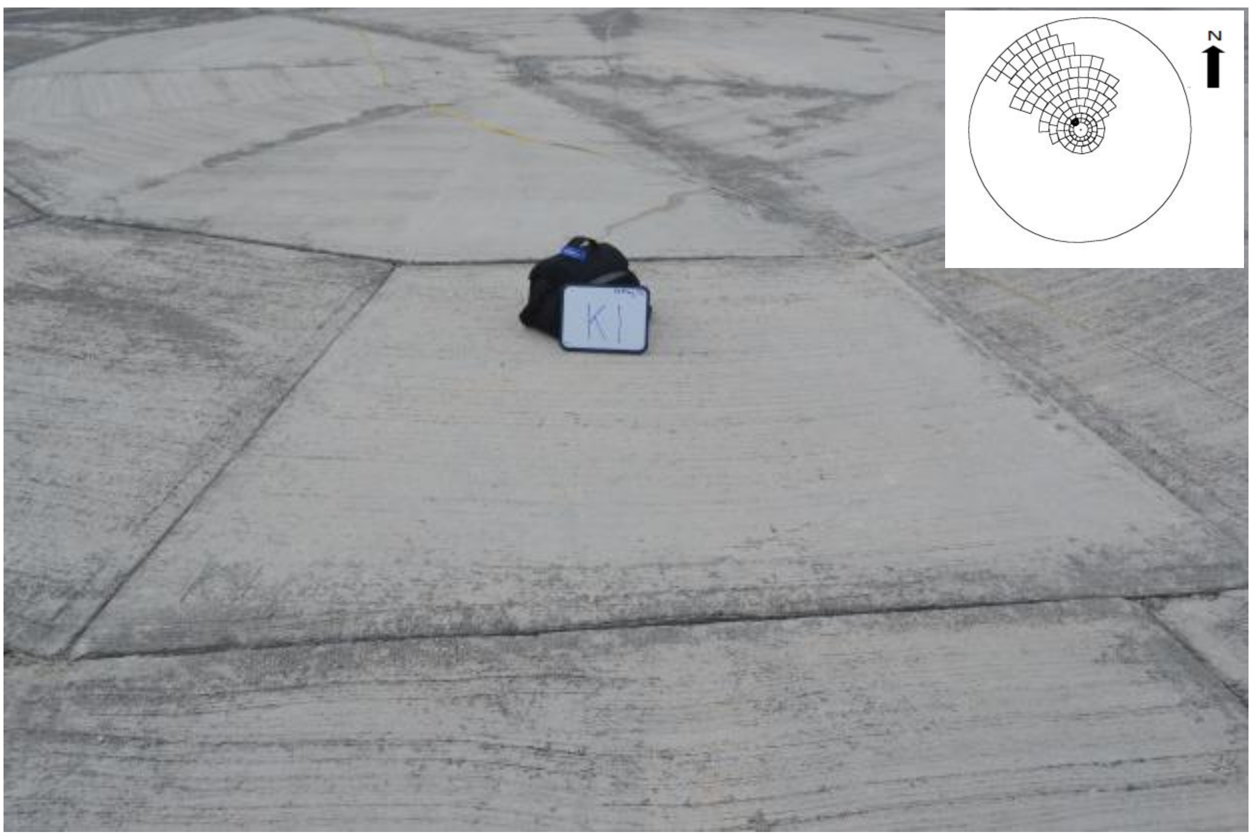
No significant or obvious interior cracks or spall elements identified with exception of very minor spalling of concrete along the seams.



CAP SECTION LOCATION: Panel K1

Description

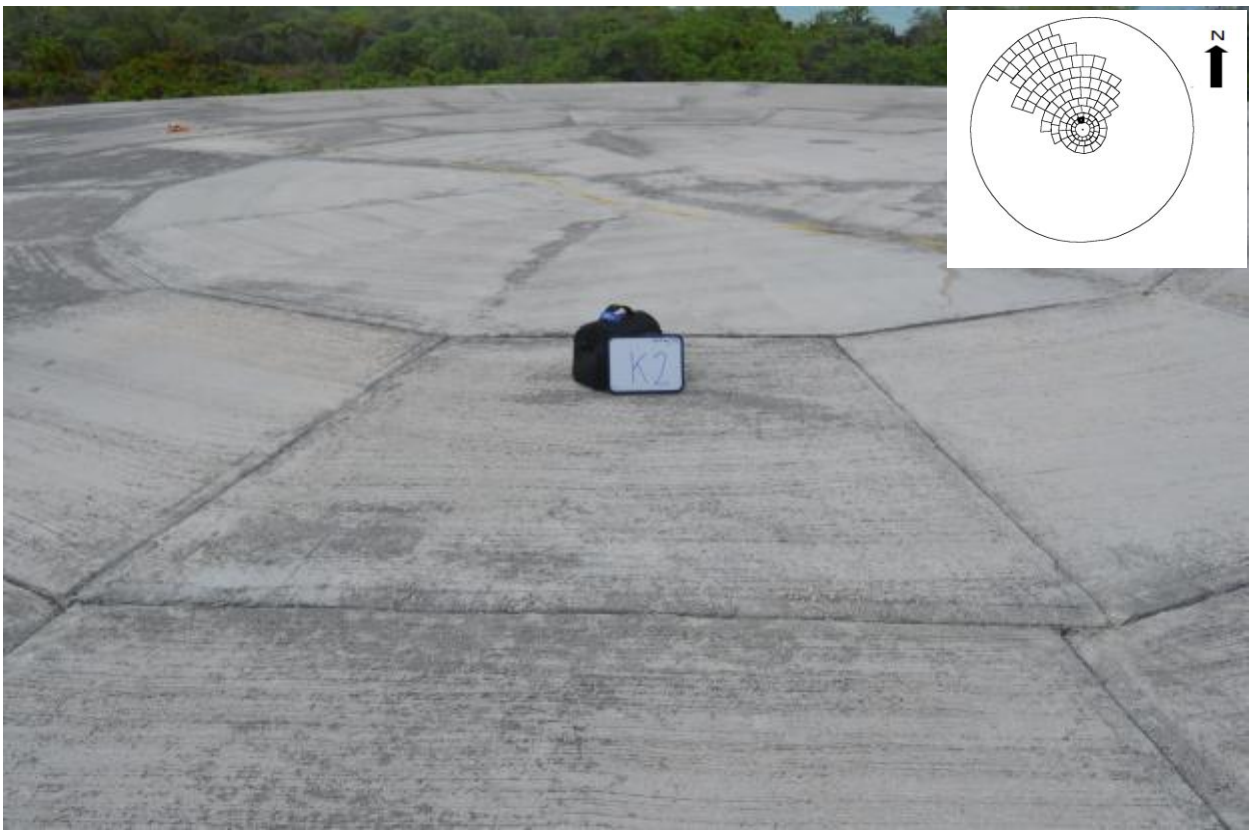
No significant or obvious interior cracks or spall elements identified. Some very minor spalling/cracking observed in the upper right corner.



CAP SECTION LOCATION: Panel K2

Description

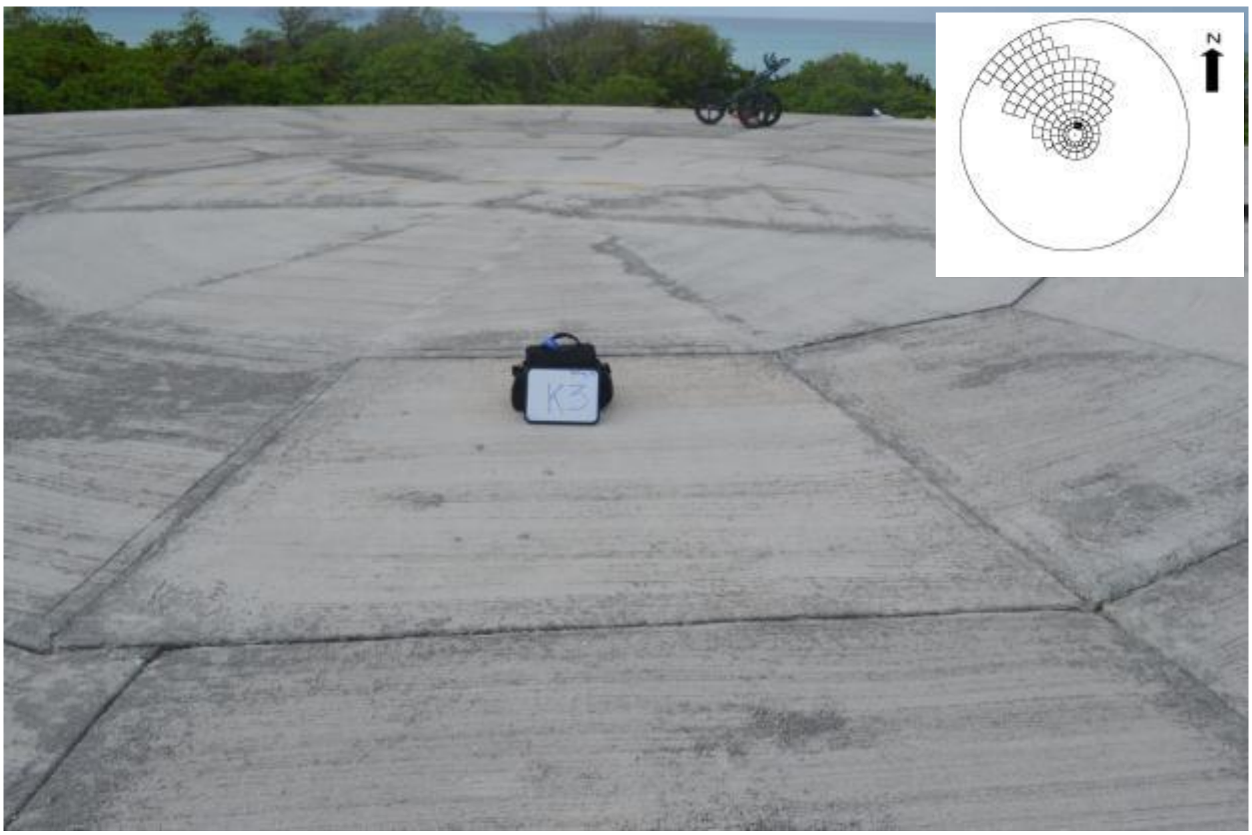
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel K3

Description

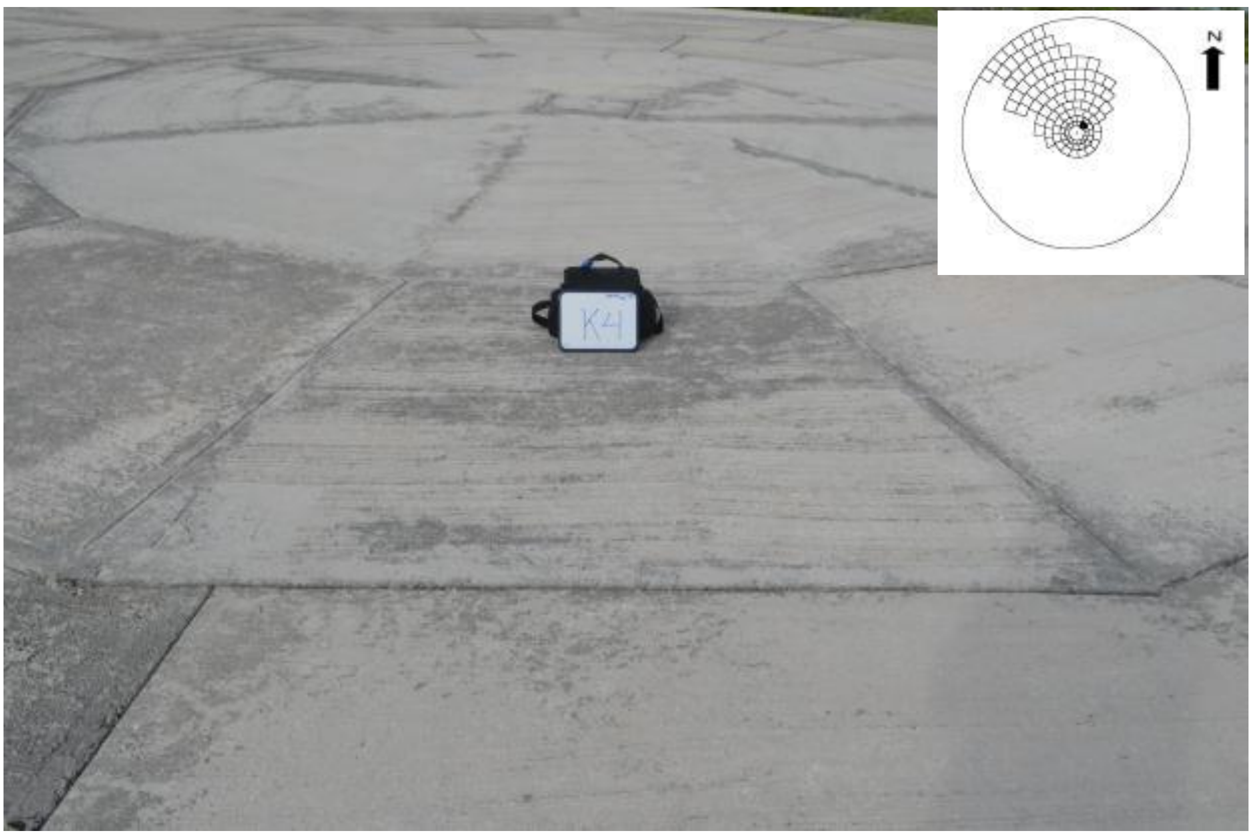
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel K4

Description

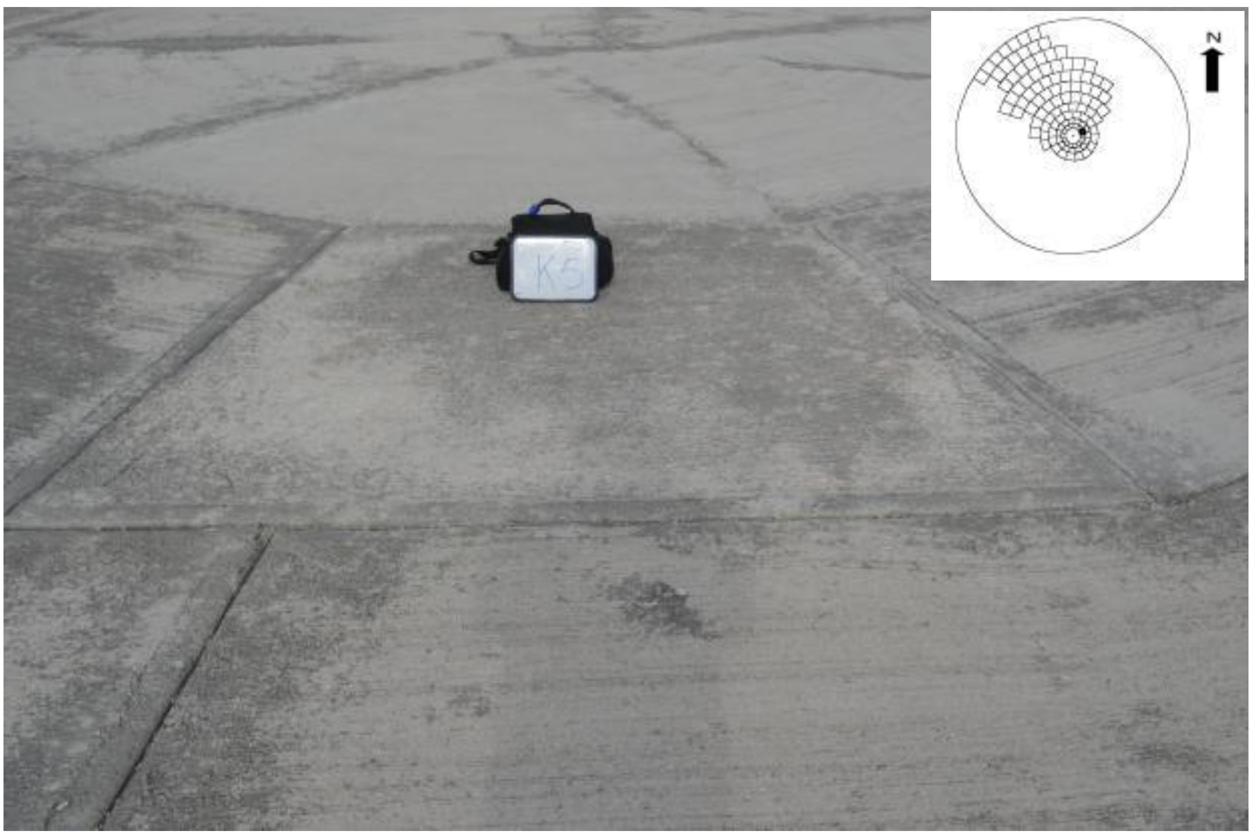
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel K5

Description

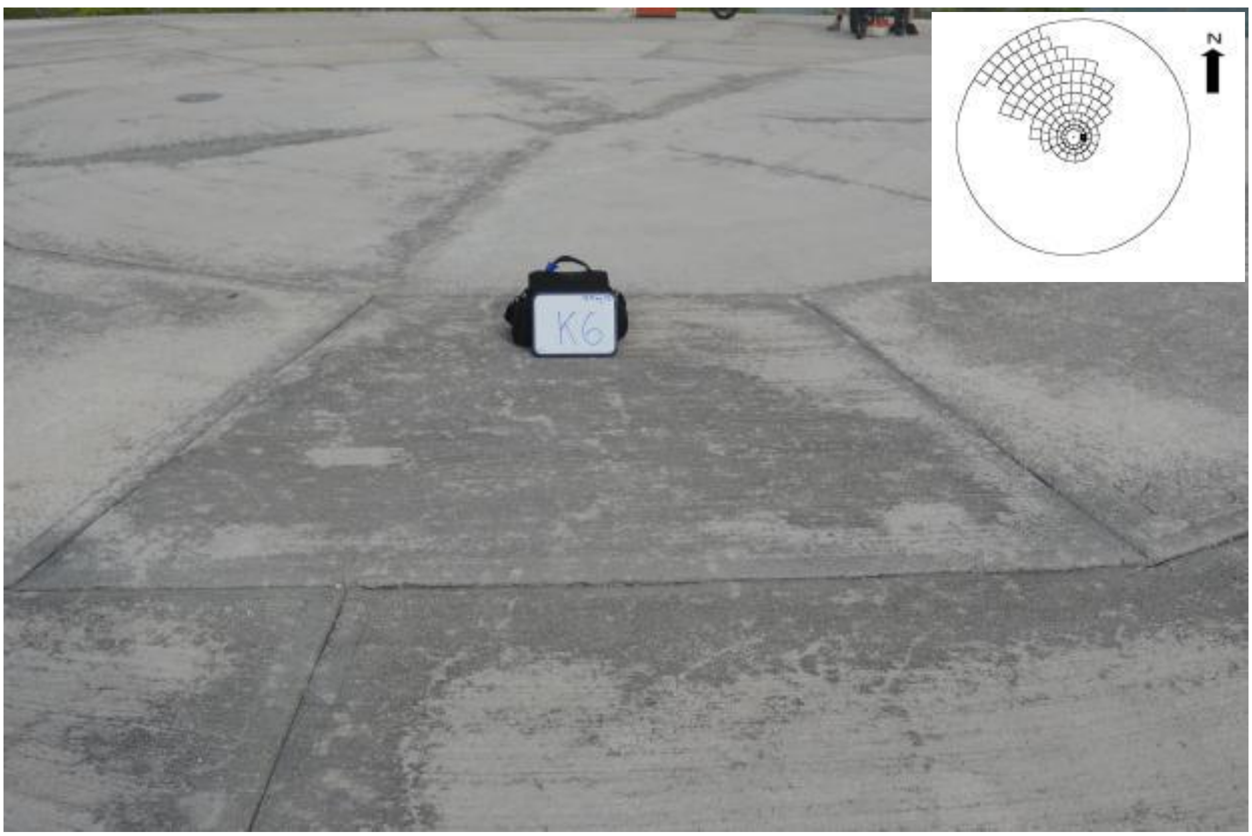
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel K6

Description

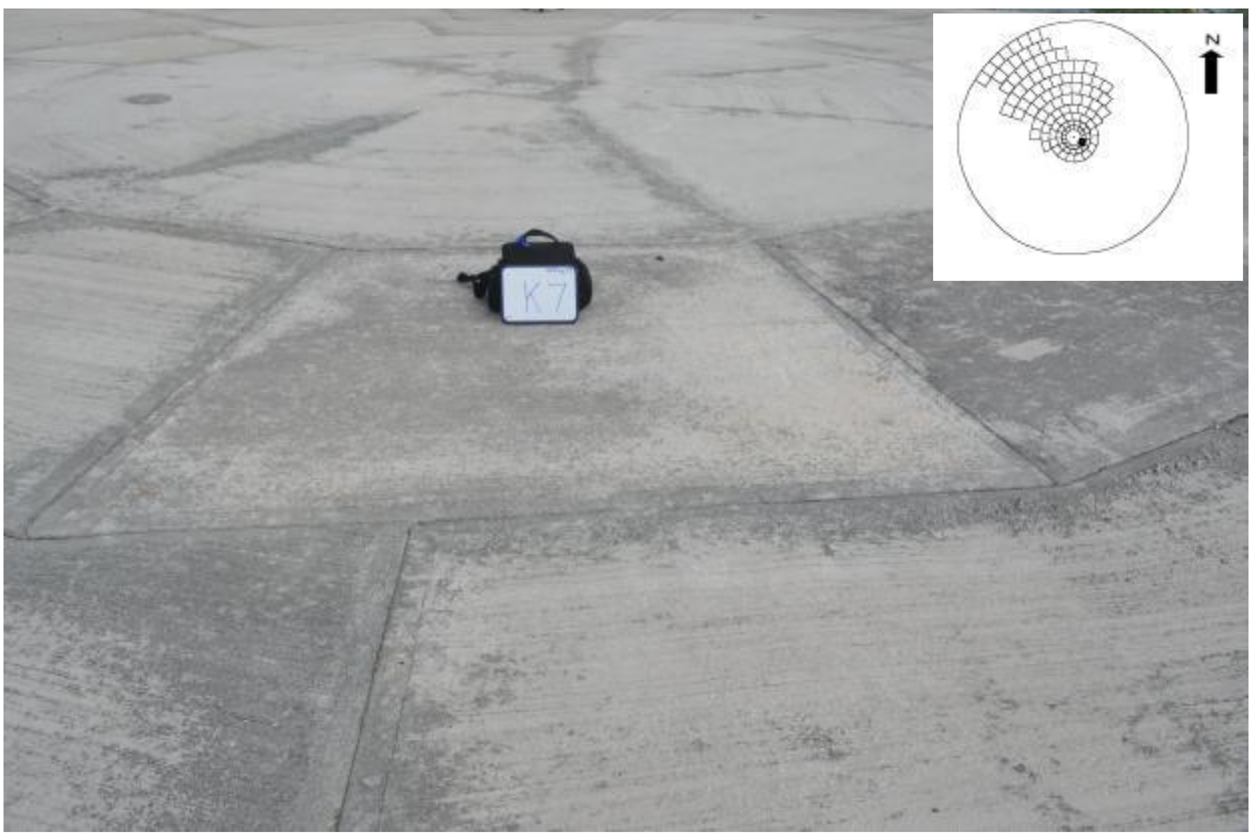
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel K7

Description

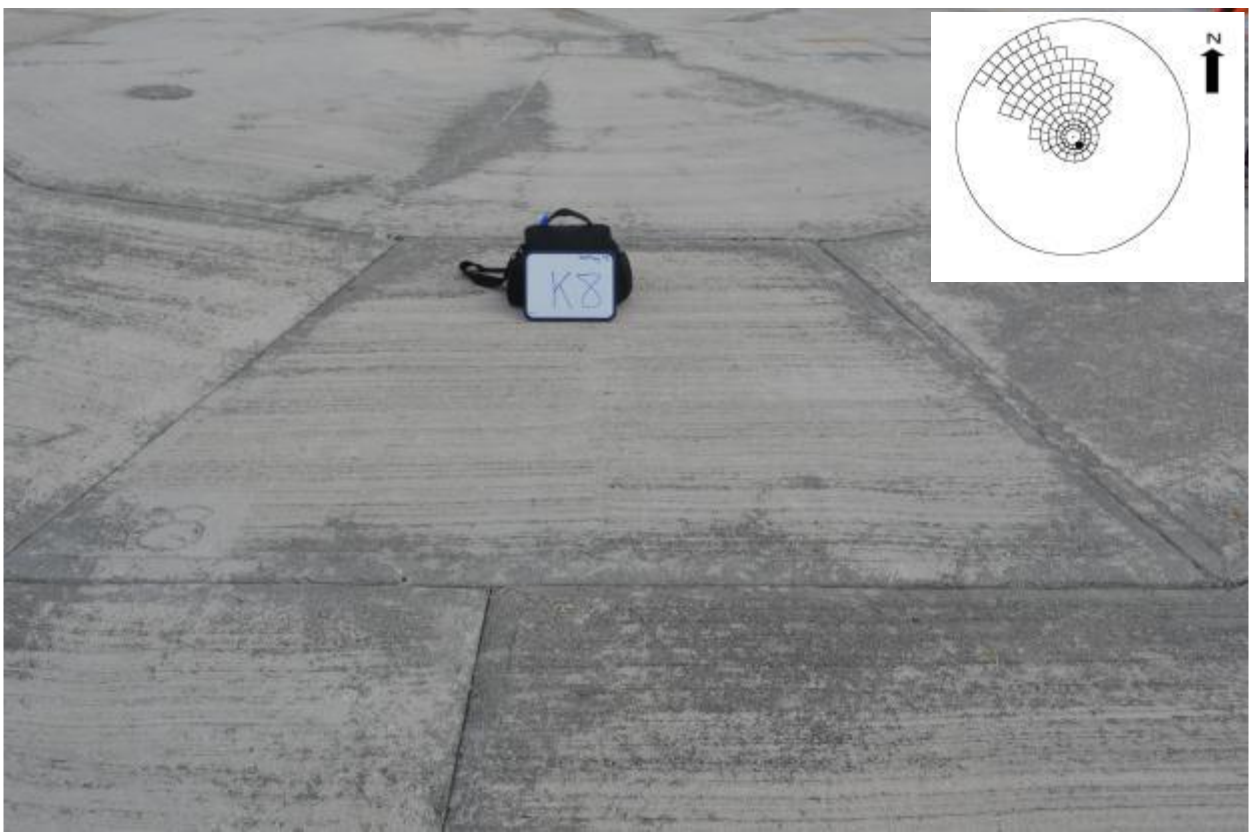
No significant or obvious interior cracks or spall elements identified with exception of a small void in the concrete in the upper right corner (app. 2 centimeters deep, and 3 x 4 centimeters in area).



CAP SECTION LOCATION: Panel K8

Description

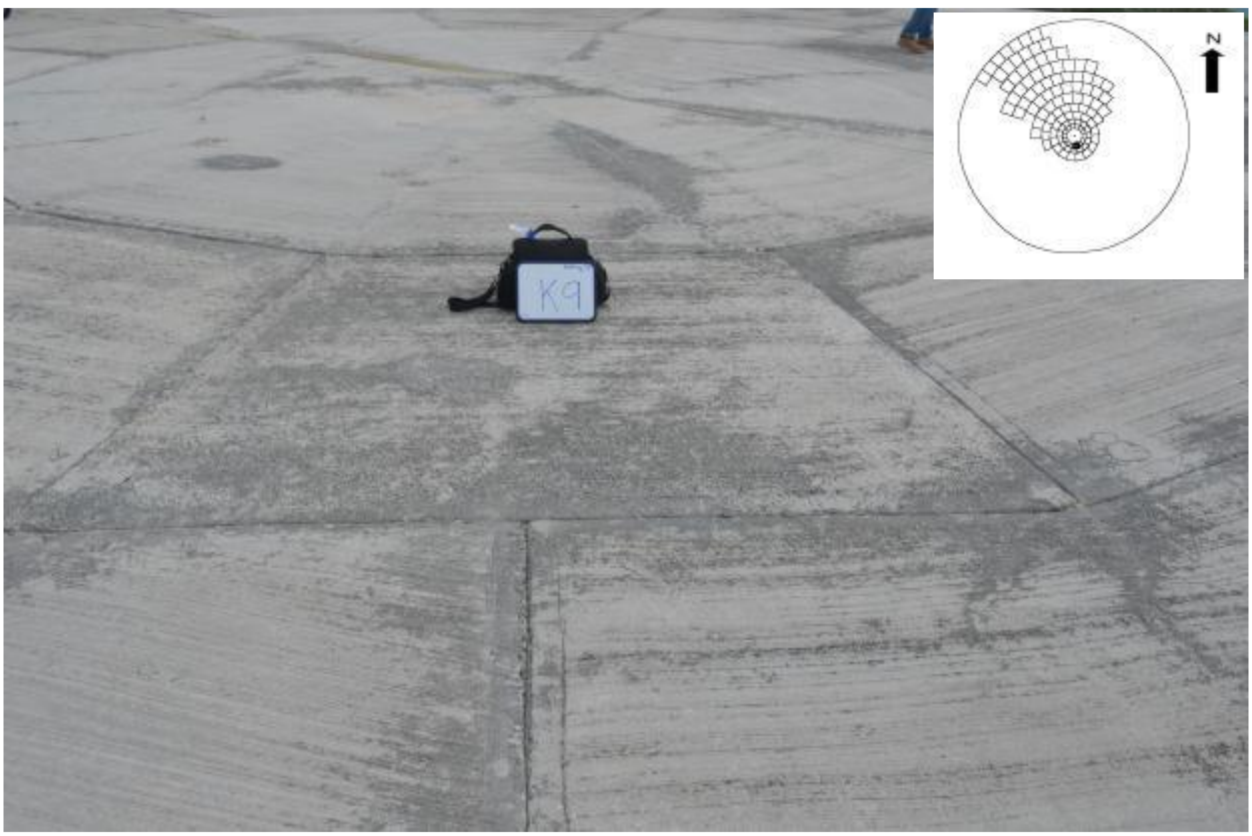
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel K9

Description

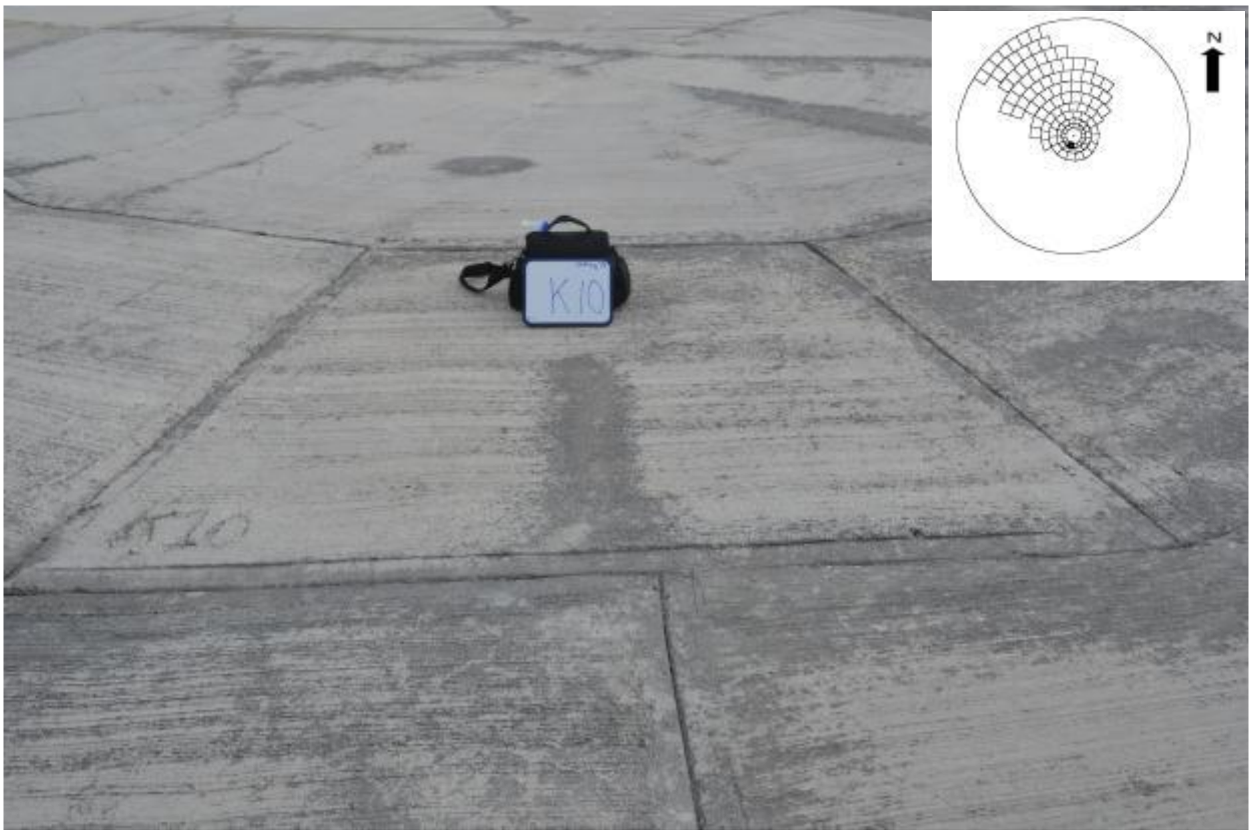
No significant or obvious interior cracks or spall elements identified. Some very minor spalling/cracking observed in the upper and lower right corners.



CAP SECTION LOCATION: Panel K10

Description

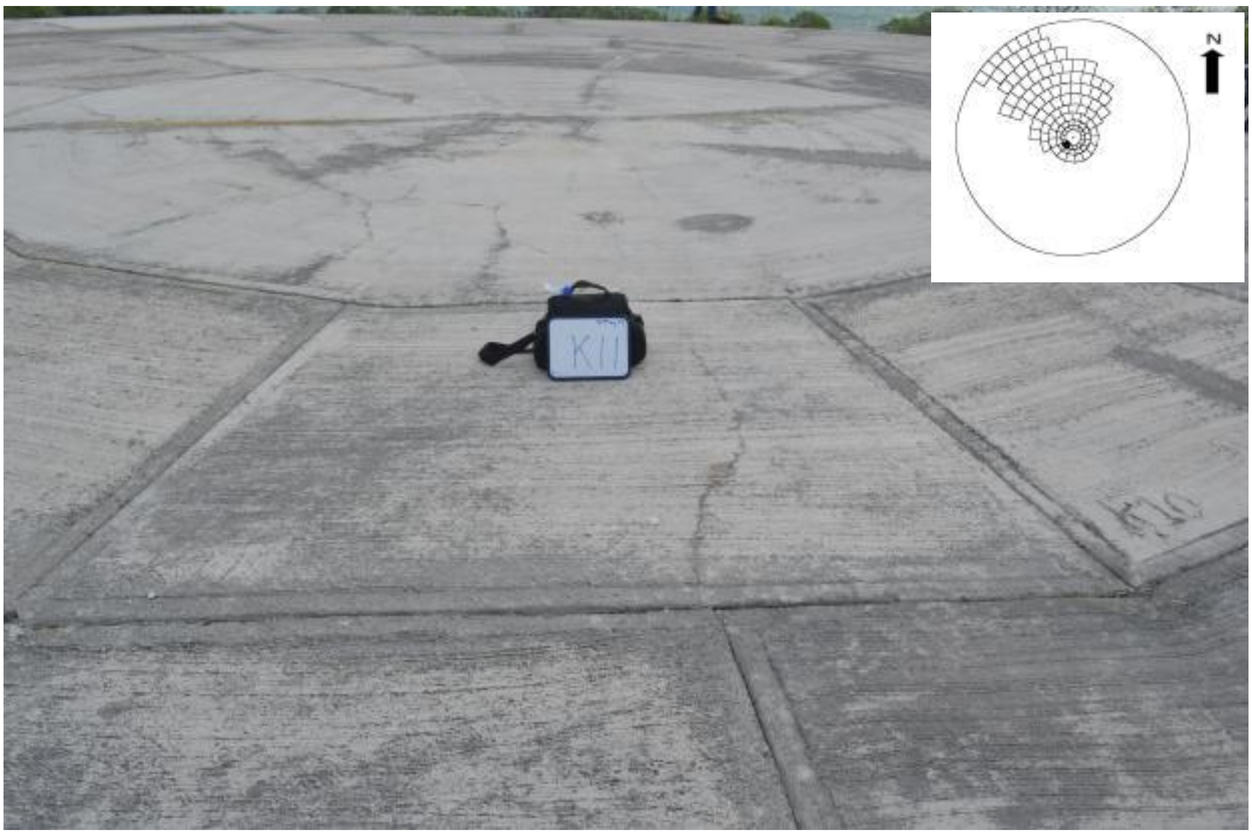
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel K11

Description

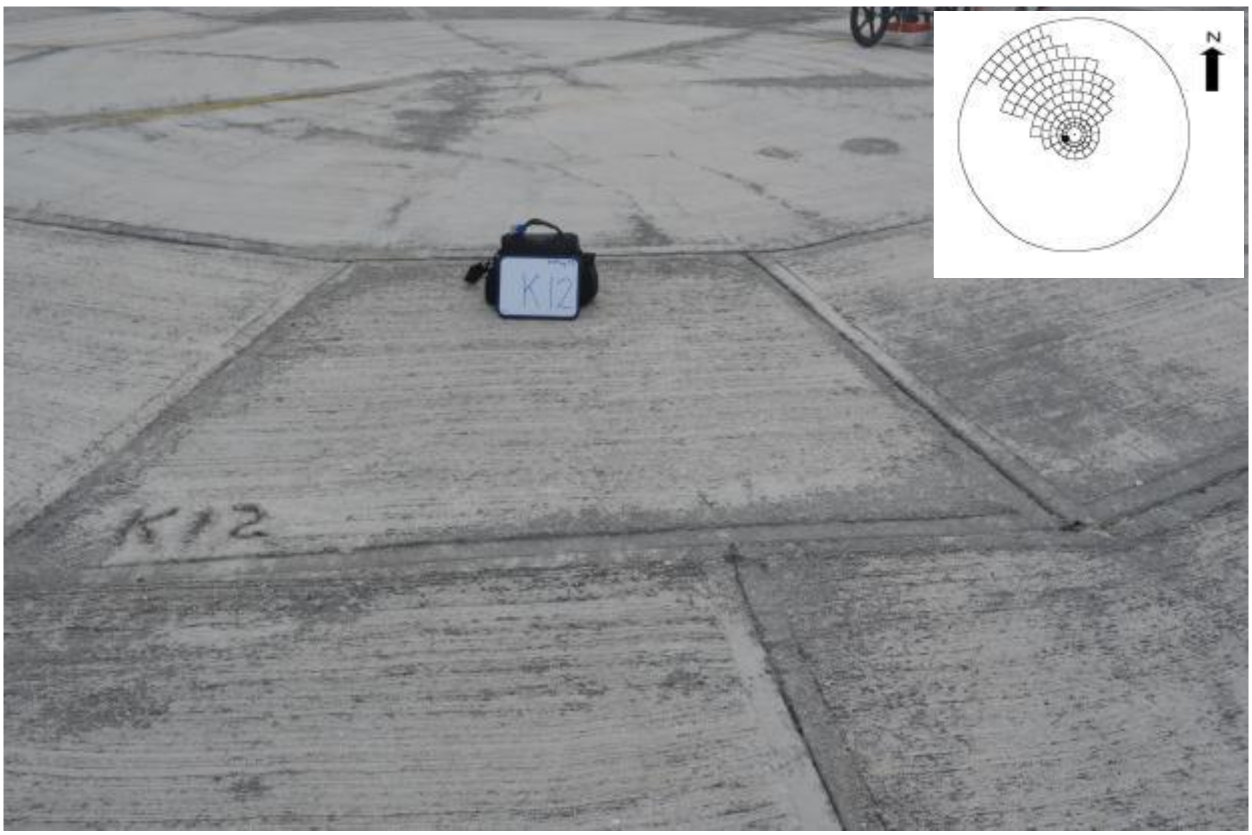
Surface crack observed running up the entire length of panel and originating from near the corner intersection of the panels on the ring row below.



CAP SECTION LOCATION: Panel K12

Description

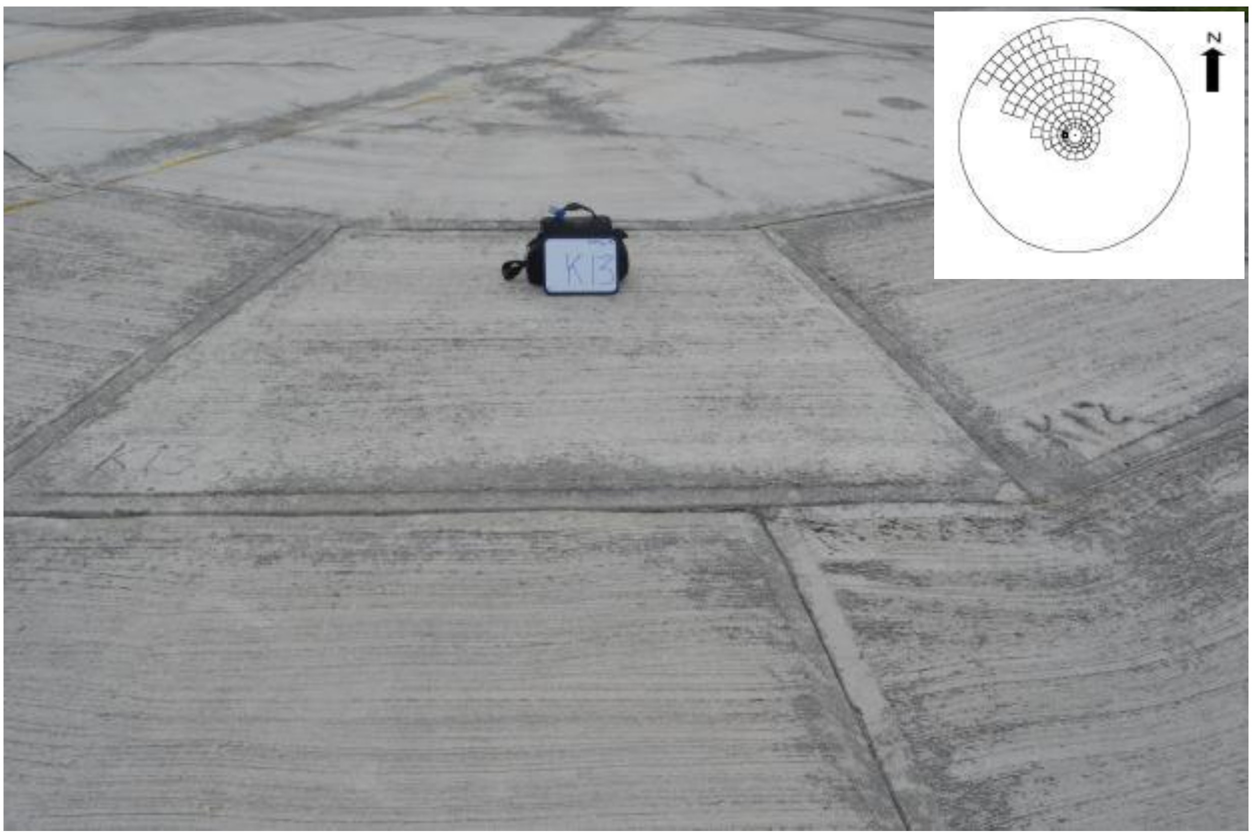
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel K13

Description

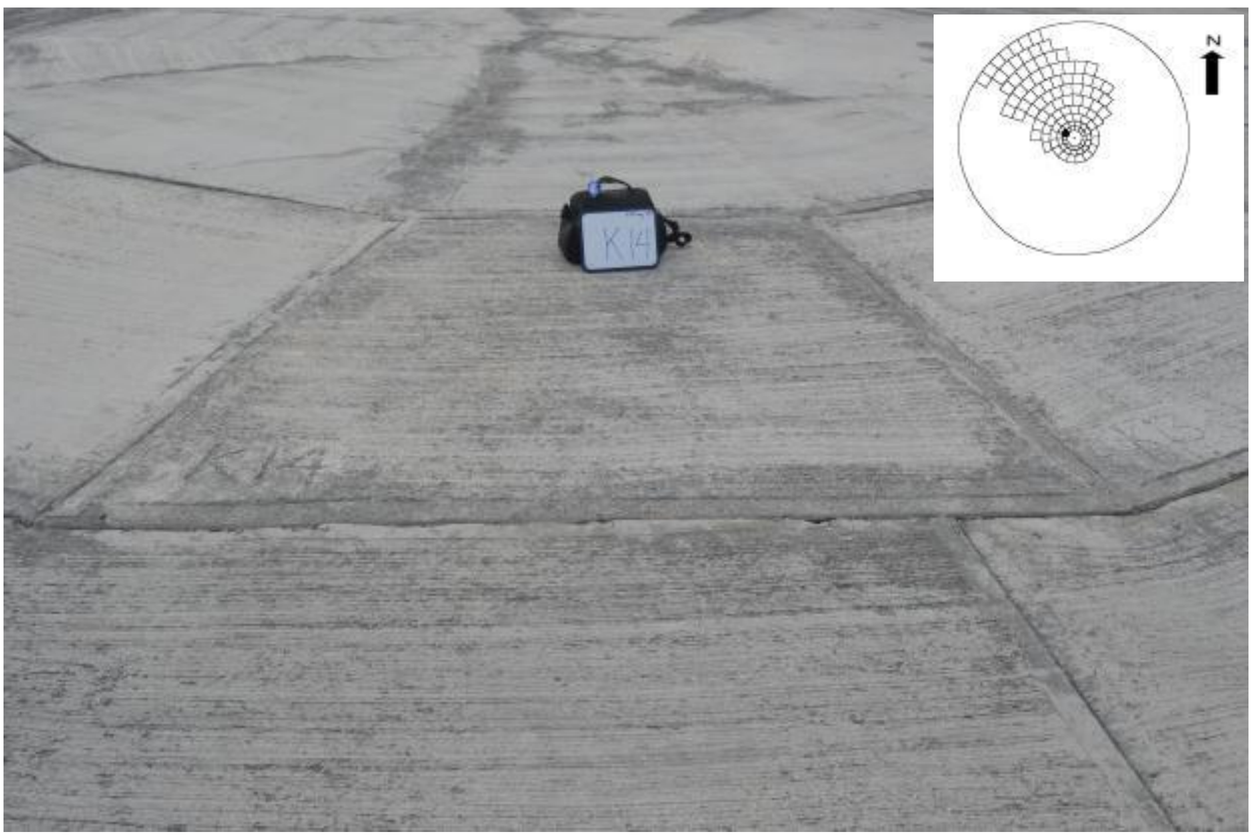
No significant or obvious interior cracks or spall elements identified with exception of very minor spalling/cracking in the lower right corner of the panel.



CAP SECTION LOCATION: Panel K14

Description

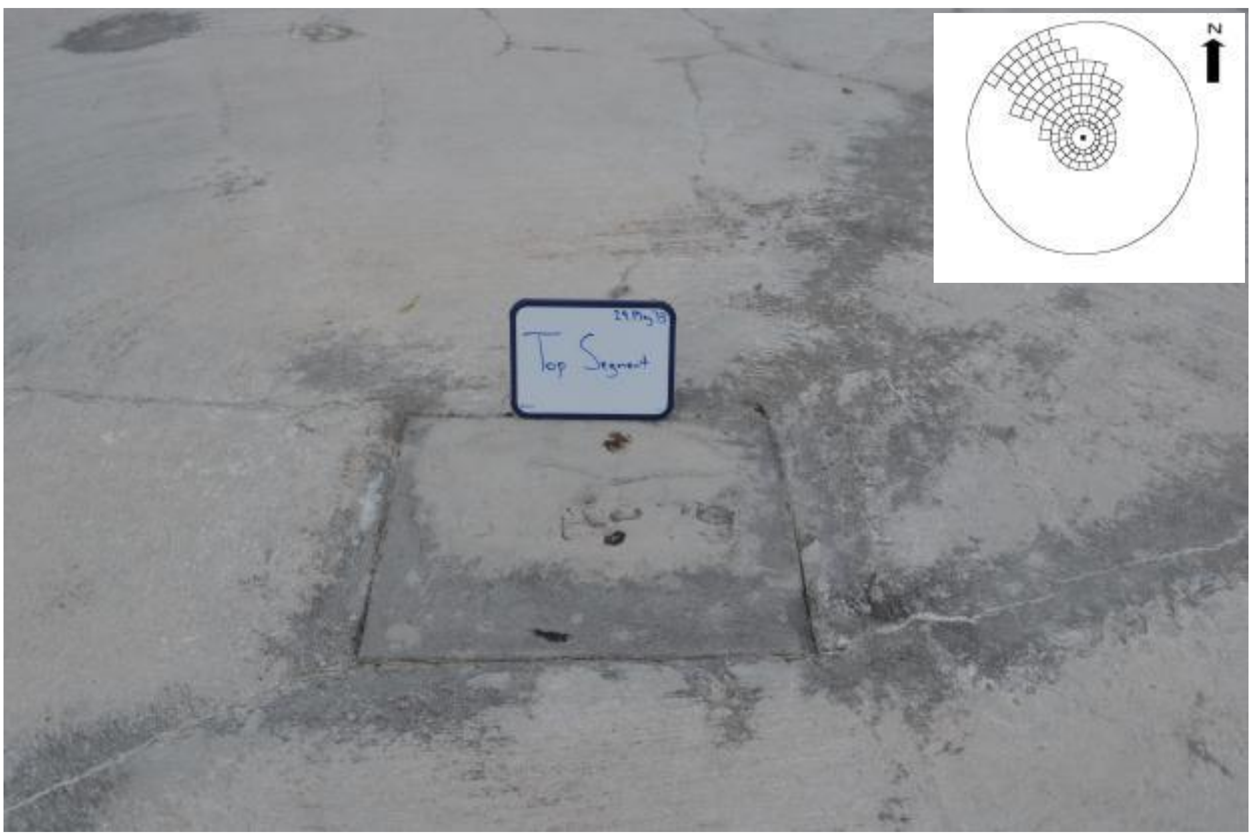
No significant or obvious interior cracks or spall elements identified.



CAP SECTION LOCATION: Panel L (Top Segment)

Description

Several surface cracks crisscrossing the segment with minor chipped "spalled' edges. The most significant cracks originate from the corners of the center top cap section of concrete.



Appendix B

Measured Coordinates (x, y, z) for the Concrete Panels Covering the Cactus crater containment structure (RTK-GNSS Survey, August 2013)

Data for all four panel corners are derived from direct measurements of the left-hand lower and upper corners only, and then taking data from the trailing segment to obtain the right side coordinates of the panel.

Table B1. RTK-GNSS Survey Data for Ring Row A.

Ring Row A	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
A1	-37.758	41.802	-7.398	-41.870	37.620	-7.449	-34.103	38.071	-5.976	-37.666	34.149	-5.987
A2	-33.218	45.674	-7.407	-37.758	41.802	-7.398	-29.656	40.768	-5.958	-34.103	38.071	-5.976
A3	-28.273	48.953	-7.423	-33.218	45.674	-7.407	-25.234	43.681	-5.955	-29.656	40.768	-5.958
A4	-23.088	51.773	-7.402	-28.273	48.953	-7.423	-20.616	46.023	-5.998	-25.234	43.681	-5.955
A5	-17.596	54.059	-7.434	-23.088	51.773	-7.402	-15.619	47.924	-5.969	-20.616	46.023	-5.998
A6	-11.864	55.728	-7.409	-17.596	54.059	-7.434	-10.449	49.541	-5.950	-15.619	47.924	-5.969
A7	-5.991	56.842	-7.381	-11.864	55.728	-7.409	-5.315	50.699	-5.995	-10.449	49.541	-5.950
A8	0.002	57.384	-7.425	-5.991	56.842	-7.381	-0.027	51.295	-5.993	-5.315	50.699	-5.995
A9	6.027	57.583	-7.394	0.002	57.384	-7.425	5.417	51.181	-5.834	-0.027	51.295	-5.993
A10	12.163	57.071	-7.449	6.027	57.583	-7.394	10.808	50.754	-5.866	5.417	51.181	-5.834
A11	18.147	55.738	-7.429	12.163	57.071	-7.449	16.085	49.347	-6.002	10.808	50.754	-5.866
A12	23.869	53.426	-7.432	18.147	55.738	-7.429	21.155	47.374	-6.011	16.085	49.347	-6.002
A13	29.296	50.502	-7.410	23.869	53.426	-7.432	25.935	44.762	-5.980	21.155	47.374	-6.011
A14	34.308	47.006	-7.414	29.296	50.502	-7.410	30.283	41.639	-5.968	25.935	44.762	-5.980
A15	38.781	43.043	-7.391	34.308	47.006	-7.414	34.668	38.315	-5.987	30.283	41.639	-5.968
A16	42.925	38.598	-7.348	38.781	43.043	-7.391	38.517	34.400	-5.999	34.668	38.315	-5.987
A17	46.558	33.832	-7.299	42.925	38.598	-7.348	41.482	30.263	-6.008	38.517	34.400	-5.999
A18	49.741	28.731	-7.286	46.558	33.832	-7.299	44.392	25.703	-5.999	41.482	30.263	-6.008
A19	52.294	23.258	-7.297	49.741	28.731	-7.286	46.736	20.756	-6.021	44.392	25.703	-5.999
A20	54.220	17.566	-7.294	52.294	23.258	-7.297	48.521	15.702	-6.021	46.736	20.756	-6.021
A21	55.686	11.740	-7.374	54.220	17.566	-7.294	49.288	10.470	-5.945	48.521	15.702	-6.021
A22	56.541	5.871	-7.386	55.686	11.740	-7.374	50.027	5.108	-5.931	49.288	10.470	-5.945
A23	56.809	-0.077	-7.363	56.541	5.871	-7.386	50.674	0.016	-5.859	50.027	5.108	-5.931
A24	56.465	-6.035	-7.272	56.809	-0.077	-7.363	50.295	-5.328	-5.767	50.674	0.016	-5.859
A25	55.553	-11.917	-7.285	56.465	-6.035	-7.272	49.437	-10.622	-5.806	50.295	-5.328	-5.767
A26	54.162	-17.761	-7.247	55.553	-11.917	-7.285	47.927	-15.755	-5.608	49.437	-10.622	-5.806

Table B1. (Continued)

Ring Row A	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
A27	52.163	-23.328	-7.216	54.162	-17.761	-7.247	46.302	-20.683	-5.618	47.927	-15.755	-5.608
A28	49.420	-28.624	-7.245	52.163	-23.328	-7.216	44.048	-25.563	-5.675	46.302	-20.683	-5.618
A29	46.274	-33.751	-7.245	49.420	-28.624	-7.245	41.244	-30.084	-5.648	44.048	-25.563	-5.675
A30	42.533	-38.432	-7.229	46.274	-33.751	-7.245	37.886	-34.234	-5.632	41.244	-30.084	-5.648
A31	38.368	-42.661	-7.217	42.533	-38.432	-7.229	34.096	-37.996	-5.647	37.886	-34.234	-5.632
A32	33.713	-46.595	-7.268	38.368	-42.661	-7.217	30.110	-41.512	-5.703	34.096	-37.996	-5.647
A33	28.712	-49.952	-7.258	33.713	-46.595	-7.268	25.530	-44.394	-5.671	30.110	-41.512	-5.703
A34	23.416	-52.768	-7.350	28.712	-49.952	-7.258	20.868	-46.903	-5.720	25.530	-44.394	-5.671
A35	17.756	-55.038	-7.274	23.416	-52.768	-7.350	15.867	-49.001	-5.834	20.868	-46.903	-5.720
A36	11.987	-56.649	-7.255	17.756	-55.038	-7.274	10.736	-50.542	-5.885	15.867	-49.001	-5.834
A37	6.031	-57.402	-7.316	11.987	-56.649	-7.255	5.280	-51.171	-5.957	10.736	-50.542	-5.885
A38	-0.028	-57.949	-7.347	6.031	-57.402	-7.316	-0.051	-51.672	-5.934	5.280	-51.171	-5.957
A39	-6.085	-57.765	-7.370	-0.028	-57.949	-7.347	-5.365	-51.352	-5.971	-0.051	-51.672	-5.934
A40	-12.148	-57.017	-7.434	-6.085	-57.765	-7.370	-10.677	-50.474	-5.902	-5.365	-51.352	-5.971
A41	-18.006	-55.509	-7.505	-12.148	-57.017	-7.434	-16.064	-49.448	-6.049	-10.677	-50.474	-5.902
A42	-23.709	-53.356	-7.447	-18.006	-55.509	-7.505	-21.008	-47.562	-6.047	-16.064	-49.448	-6.049
A43	-29.179	-50.530	-7.421	-23.709	-53.356	-7.447	-25.992	-44.921	-6.019	-21.008	-47.562	-6.047
A44	-34.037	-46.930	-7.434	-29.179	-50.530	-7.421	-30.292	-41.775	-5.950	-25.992	-44.921	-6.019
A45	-38.524	-42.899	-7.448	-34.037	-46.930	-7.434	-34.341	-38.231	-5.928	-30.292	-41.775	-5.950
A46	-42.683	-38.581	-7.449	-38.524	-42.899	-7.448	-37.820	-34.194	-5.972	-34.341	-38.231	-5.928
A47	-46.331	-33.964	-7.433	-42.683	-38.581	-7.449	-41.152	-30.140	-5.946	-37.820	-34.194	-5.972
A48	-49.716	-28.944	-7.500	-46.331	-33.964	-7.433	-44.039	-25.744	-5.959	-41.152	-30.140	-5.946
A49	-52.438	-23.584	-7.415	-49.716	-28.944	-7.500	-46.508	-20.946	-6.031	-44.039	-25.744	-5.959
A50	-54.716	-17.976	-7.361	-52.438	-23.584	-7.415	-48.797	-16.008	-6.097	-46.508	-20.946	-6.031
A51	-56.379	-12.135	-7.397	-54.716	-17.976	-7.361	-50.012	-10.816	-6.054	-48.797	-16.008	-6.097
A52	-57.256	-6.186	-7.383	-56.379	-12.135	-7.397	-50.575	-5.483	-6.005	-50.012	-10.816	-6.054
A53	-57.610	-0.151	-7.336	-57.256	-6.186	-7.383	-50.916	-0.125	-6.016	-50.575	-5.483	-6.005

Table B1. (Continued)

Ring Row A	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
A54	-57.223	5.951	-7.362	-57.610	-0.151	-7.336	-50.703	5.240	-6.037	-50.916	-0.125	-6.016
A55	-56.094	11.853	-7.339	-57.223	5.951	-7.362	-49.749	10.431	-6.020	-50.703	5.240	-6.037
A56	-54.263	17.513	-7.355	-56.094	11.853	-7.339	-48.276	15.488	-5.969	-49.749	10.431	-6.020
A57	-51.888	23.044	-7.369	-54.263	17.513	-7.355	-46.143	20.547	-5.957	-48.276	15.488	-5.969
A58	-48.908	28.291	-7.397	-51.888	23.044	-7.369	-43.774	25.091	-5.948	-46.143	20.547	-5.957
A59	-45.691	33.097	-7.383	-48.908	28.291	-7.397	-40.895	29.586	-5.980	-43.774	25.091	-5.948
A60	-41.870	37.620	-7.449	-45.691	33.097	-7.383	-37.666	34.149	-5.987	-40.895	29.586	-5.980

Table B2. RTK-GNSS Survey Data for Ring Row B.

Ring Row B	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
B1	-37.314	34.548	-5.981	-40.722	29.708	-5.960	-32.427	29.935	-4.518	-35.727	26.081	-4.552
B2	-33.079	38.628	-5.943	-37.314	34.548	-5.981	-28.689	33.569	-4.486	-32.427	29.935	-4.518
B3	-28.203	41.771	-5.956	-33.079	38.628	-5.943	-25.021	36.968	-4.613	-28.689	33.569	-4.486
B4	-23.125	44.756	-6.001	-28.203	41.771	-5.956	-20.478	39.615	-4.607	-25.021	36.968	-4.613
B5	-17.762	47.111	-6.000	-23.125	44.756	-6.001	-15.764	41.795	-4.563	-20.478	39.615	-4.607
B6	-12.185	48.965	-5.960	-17.762	47.111	-6.000	-10.777	43.432	-4.570	-15.764	41.795	-4.563
B7	-6.474	50.437	-5.996	-12.185	48.965	-5.960	-5.671	44.308	-4.544	-10.777	43.432	-4.570
B8	-0.588	51.201	-6.022	-6.474	50.437	-5.996	-0.506	45.023	-4.588	-5.671	44.308	-4.544
B9	5.421	51.172	-5.842	-0.588	51.201	-6.022	4.775	44.925	-4.572	-0.506	45.023	-4.588
B10	11.432	50.478	-5.882	5.421	51.172	-5.842	9.981	44.215	-4.547	4.775	44.925	-4.572
B11	17.236	48.973	-6.022	11.432	50.478	-5.882	14.949	42.395	-4.537	9.981	44.215	-4.547
B12	22.770	46.448	-5.989	17.236	48.973	-6.022	19.776	40.255	-4.526	14.949	42.395	-4.537
B13	27.914	43.345	-5.977	22.770	46.448	-5.989	24.275	37.691	-4.557	19.776	40.255	-4.526
B14	32.730	39.792	-5.990	27.914	43.345	-5.977	28.481	34.520	-4.566	24.275	37.691	-4.557
B15	37.195	35.792	-6.000	32.730	39.792	-5.990	32.411	31.123	-4.518	28.481	34.520	-4.566
B16	40.965	30.968	-6.023	37.195	35.792	-6.000	35.903	27.047	-4.588	32.411	31.123	-4.518
B17	44.157	26.083	-5.979	40.965	30.968	-6.023	38.224	22.681	-4.540	35.903	27.047	-4.588
B18	46.736	20.729	-6.006	44.157	26.083	-5.979	40.671	18.024	-4.568	38.224	22.681	-4.540
B19	48.533	15.117	-6.006	46.736	20.729	-6.006	42.457	13.197	-4.569	40.671	18.024	-4.568
B20	49.422	9.258	-5.941	48.533	15.117	-6.006	43.716	8.098	-4.533	42.457	13.197	-4.569
B21	50.213	3.523	-5.942	49.422	9.258	-5.941	44.562	3.113	-4.564	43.716	8.098	-4.533
B22	50.563	-2.346	-5.819	50.213	3.523	-5.942	44.534	-2.177	-4.561	44.562	3.113	-4.564
B23	49.792	-8.320	-5.807	50.563	-2.346	-5.819	43.859	-7.261	-4.516	44.534	-2.177	-4.561
B24	48.412	-14.012	-5.684	49.792	-8.320	-5.807	42.673	-12.362	-4.497	43.859	-7.261	-4.516
B25	46.539	-19.924	-5.633	48.412	-14.012	-5.684	40.850	-17.521	-4.479	42.673	-12.362	-4.497
B26	43.936	-25.687	-5.666	46.539	-19.924	-5.633	38.758	-22.621	-4.487	40.850	-17.521	-4.479

Table B2. (Continued)

Ring Row B	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
B27	41.220	-30.098	-5.670	43.936	-25.687	-5.666	36.233	-26.267	-4.481	38.758	-22.621	-4.487
B28	37.436	-34.610	-5.603	41.220	-30.098	-5.670	33.004	-30.429	-4.467	36.233	-26.267	-4.481
B29	33.306	-38.694	-5.643	37.436	-34.610	-5.603	29.273	-34.003	-4.521	33.004	-30.429	-4.467
B30	28.655	-42.430	-5.697	33.306	-38.694	-5.643	25.146	-37.175	-4.534	29.273	-34.003	-4.521
B31	23.593	-45.487	-5.706	28.655	-42.430	-5.697	20.716	-39.820	-4.455	25.146	-37.175	-4.534
B32	18.081	-48.088	-5.797	23.593	-45.487	-5.706	15.854	-41.827	-4.438	20.716	-39.820	-4.455
B33	12.554	-50.059	-5.859	18.081	-48.088	-5.797	10.928	-43.719	-4.426	15.854	-41.827	-4.438
B34	6.520	-51.018	-5.952	12.554	-50.059	-5.859	5.798	-44.610	-4.426	10.928	-43.719	-4.426
B35	0.651	-51.628	-5.933	6.520	-51.018	-5.952	0.453	-45.152	-4.541	5.798	-44.610	-4.426
B36	-5.350	-51.315	-5.954	0.651	-51.628	-5.933	-4.793	-44.841	-4.539	0.453	-45.152	-4.541
B37	-11.189	-50.306	-5.901	-5.350	-51.315	-5.954	-9.844	-44.052	-4.538	-4.793	-44.841	-4.539
B38	-17.134	-49.033	-6.036	-11.189	-50.306	-5.901	-14.931	-42.559	-4.542	-9.844	-44.052	-4.538
B39	-22.638	-46.656	-6.020	-17.134	-49.033	-6.036	-19.717	-40.755	-4.545	-14.931	-42.559	-4.542
B40	-27.802	-43.583	-5.993	-22.638	-46.656	-6.020	-24.218	-38.085	-4.534	-19.717	-40.755	-4.545
B41	-32.474	-39.866	-5.929	-27.802	-43.583	-5.993	-28.286	-34.763	-4.529	-24.218	-38.085	-4.534
B42	-36.601	-35.626	-5.987	-32.474	-39.866	-5.929	-31.968	-31.019	-4.526	-28.286	-34.763	-4.529
B52	-40.358	-31.054	-5.938	-36.601	-35.626	-5.987	-35.124	-27.098	-4.573	-31.968	-31.019	-4.526
B53	-43.720	-26.203	-5.958	-40.358	-31.054	-5.938	-38.006	-22.721	-4.580	-35.124	-27.098	-4.573
B54	-46.461	-20.944	-6.023	-43.720	-26.203	-5.958	-40.508	-18.239	-4.545	-38.006	-22.721	-4.580
B55	-48.917	-15.486	-6.084	-46.461	-20.944	-6.023	-42.638	-13.503	-4.581	-40.508	-18.239	-4.545
B56	-50.068	-9.562	-6.028	-48.917	-15.486	-6.084	-43.680	-8.348	-4.549	-42.638	-13.503	-4.581
B57	-50.692	-3.719	-6.021	-50.068	-9.562	-6.028	-44.174	-3.156	-4.550	-43.680	-8.348	-4.549
B58	-50.790	2.171	-5.997	-50.692	-3.719	-6.021	-44.384	1.863	-4.561	-44.174	-3.156	-4.550
B55_2	-50.162	8.110	-6.015	-50.790	2.171	-5.997	-43.850	7.059	-4.508	-44.384	1.863	-4.561
B56_2	-48.689	13.986	-5.974	-50.162	8.110	-6.015	-42.658	12.040	-4.523	-43.850	7.059	-4.508
B57_2	-46.559	19.575	-5.953	-48.689	13.986	-5.974	-40.716	17.078	-4.514	-42.658	12.040	-4.523
No ID	-43.893	24.757	-5.975	-46.559	19.575	-5.953	-38.565	21.701	-4.523	-40.716	17.078	-4.514
B59	-40.722	29.708	-5.960	-43.893	24.757	-5.975	-35.727	26.081	-4.552	-38.565	21.701	-4.523

Table B3. RTK-GNSS Survey Data for Ring Row C.

Ring Row C	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
C1	-25.285	36.720	-4.616	-29.514	32.760	-4.507	-21.739	31.608	-3.320	-25.711	28.596	-3.283
C2	-20.259	39.624	-4.594	-25.285	36.720	-4.616	-17.519	34.282	-3.394	-21.739	31.608	-3.320
C3	-14.911	42.075	-4.558	-20.259	39.624	-4.594	-12.773	36.206	-3.401	-17.519	34.282	-3.394
C4	-9.415	43.628	-4.566	-14.911	42.075	-4.558	-8.042	37.509	-3.390	-12.773	36.206	-3.401
C5	-3.390	44.662	-4.566	-9.415	43.628	-4.566	-3.018	38.277	-3.392	-8.042	37.509	-3.390
C6	2.303	44.998	-4.595	-3.390	44.662	-4.566	2.060	38.375	-3.395	-3.018	38.277	-3.392
C7	8.289	44.433	-4.560	2.303	44.998	-4.595	7.163	37.883	-3.382	2.060	38.375	-3.395
C8	13.916	42.719	-4.531	8.289	44.433	-4.560	11.983	36.470	-3.351	7.163	37.883	-3.382
C9	19.432	40.428	-4.532	13.916	42.719	-4.531	16.780	34.486	-3.328	11.983	36.470	-3.351
C10	24.492	37.510	-4.560	19.432	40.428	-4.532	20.946	32.124	-3.336	16.780	34.486	-3.328
C11	29.094	33.920	-4.542	24.492	37.510	-4.560	25.055	29.071	-3.354	20.946	32.124	-3.336
C12	33.423	29.972	-4.521	29.094	33.920	-4.542	28.685	25.785	-3.350	25.055	29.071	-3.354
C13	36.783	25.244	-4.545	33.423	29.972	-4.521	31.705	21.673	-3.360	28.685	25.785	-3.350
C14	39.657	20.043	-4.549	36.783	25.244	-4.545	34.312	17.272	-3.339	31.705	21.673	-3.360
C15	41.879	14.712	-4.562	39.657	20.043	-4.549	36.316	12.552	-3.338	34.312	17.272	-3.339
C16	43.474	9.115	-4.529	41.879	14.712	-4.562	37.592	7.871	-3.386	36.316	12.552	-3.338
C17	44.490	3.365	-4.568	43.474	9.115	-4.529	38.396	2.820	-3.386	37.592	7.871	-3.386
C18	44.425	-2.454	-4.540	44.490	3.365	-4.568	38.490	-2.044	-3.407	38.396	2.820	-3.386
C19	43.696	-8.190	-4.522	44.425	-2.454	-4.540	37.993	-7.127	-3.457	38.490	-2.044	-3.407
C20	42.118	-13.806	-4.481	43.696	-8.190	-4.522	36.608	-12.007	-3.402	37.993	-7.127	-3.457
C21	40.119	-19.312	-4.490	42.118	-13.806	-4.481	34.642	-16.638	-3.385	36.608	-12.007	-3.402
C22	37.524	-24.446	-4.478	40.119	-19.312	-4.490	32.184	-20.983	-3.434	34.642	-16.638	-3.385
C23	34.055	-29.172	-4.468	37.524	-24.446	-4.478	29.335	-25.144	-3.487	32.184	-20.983	-3.434
C22_dup	29.940	-33.371	-4.510	34.055	-29.172	-4.468	25.789	-28.835	-3.471	29.335	-25.144	-3.487
C25	25.398	-37.011	-4.543	29.940	-33.371	-4.510	21.834	-31.795	-3.511	25.789	-28.835	-3.471

Table B3. (Continued)

Ring Row C	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
C26	20.382	-40.011	-4.468	25.398	-37.011	-4.543	17.484	-34.446	-3.440	21.834	-31.795	-3.511
C27	14.867	-42.137	-4.461	20.382	-40.011	-4.468	12.732	-36.398	-3.450	17.484	-34.446	-3.440
C28	9.393	-44.033	-4.411	14.867	-42.137	-4.461	7.811	-37.785	-3.394	12.732	-36.398	-3.450
C29	3.576	-44.838	-4.492	9.393	-44.033	-4.411	3.018	-38.403	-3.395	7.811	-37.785	-3.394
C30	-2.343	-45.061	-4.560	3.576	-44.838	-4.492	-2.091	-38.489	-3.381	3.018	-38.403	-3.395
C31	-8.126	-44.316	-4.534	-2.343	-45.061	-4.560	-6.900	-37.976	-3.407	-2.091	-38.489	-3.381
C32	-13.883	-42.894	-4.548	-8.126	-44.316	-4.534	-11.883	-36.864	-3.433	-6.900	-37.976	-3.407
C33	-19.460	-40.881	-4.549	-13.883	-42.894	-4.548	-16.732	-35.467	-3.458	-11.883	-36.864	-3.433
C34	-24.513	-37.809	-4.528	-19.460	-40.881	-4.549	-20.964	-32.571	-3.423	-16.732	-35.467	-3.458
C35	-28.994	-34.129	-4.529	-24.513	-37.809	-4.528	-24.876	-29.346	-3.327	-20.964	-32.571	-3.423
C36	-32.986	-29.808	-4.538	-28.994	-34.129	-4.529	-28.528	-25.720	-3.341	-24.876	-29.346	-3.327
C37	-36.423	-25.140	-4.558	-32.986	-29.808	-4.538	-31.530	-21.933	-3.383	-28.528	-25.720	-3.341
C38	-39.422	-20.211	-4.576	-36.423	-25.140	-4.558	-34.199	-17.480	-3.346	-31.530	-21.933	-3.383
C39	-41.988	-14.968	-4.578	-39.422	-20.211	-4.576	-36.186	-12.855	-3.366	-34.199	-17.480	-3.346
C40	-43.514	-9.357	-4.570	-41.988	-14.968	-4.578	-37.537	-8.029	-3.384	-36.186	-12.855	-3.366
C41	-44.131	-3.590	-4.537	-43.514	-9.357	-4.570	-38.363	-3.140	-3.415	-37.537	-8.029	-3.384
C42	-44.358	2.206	-4.558	-44.131	-3.590	-4.537	-38.596	1.937	-3.378	-38.363	-3.140	-3.415
C43	-43.639	8.004	-4.528	-44.358	2.206	-4.558	-37.750	6.926	-3.341	-38.596	1.937	-3.378
C44	-42.082	13.667	-4.538	-43.639	8.004	-4.528	-36.568	11.883	-3.314	-37.750	6.926	-3.341
C45	-39.856	18.954	-4.520	-42.082	13.667	-4.538	-34.724	16.492	-3.315	-36.568	11.883	-3.314
C46	-37.047	24.063	-4.530	-39.856	18.954	-4.520	-32.136	20.957	-3.312	-34.724	16.492	-3.315
C47	-33.525	28.599	-4.529	-37.047	24.063	-4.530	-29.137	24.830	-3.300	-32.136	20.957	-3.312
C48	-29.514	32.760	-4.507	-33.525	28.599	-4.529	-25.711	28.596	-3.283	-29.137	24.830	-3.300

Table B4. RTK-GNSS Survey Data for Ring Row D.

Ring Row D	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
D1	-17.581	34.334	-3.390	-22.612	30.975	-3.308	-14.755	28.901	-2.429	-19.139	26.222	-2.430
D2	-11.856	36.453	-3.386	-17.581	34.334	-3.390	-9.980	30.684	-2.459	-14.755	28.901	-2.429
D3	-6.036	37.841	-3.385	-11.856	36.453	-3.386	-5.077	31.820	-2.457	-9.980	30.684	-2.459
D4	0.016	38.328	-3.396	-6.036	37.841	-3.385	-0.080	32.174	-2.457	-5.077	31.820	-2.457
D5	5.981	37.985	-3.380	0.016	38.328	-3.396	4.978	31.997	-2.448	-0.080	32.174	-2.457
D6	11.859	36.467	-3.361	5.981	37.985	-3.380	9.950	30.674	-2.421	4.978	31.997	-2.448
D7	17.355	34.151	-3.342	11.859	36.467	-3.361	14.522	28.706	-2.424	9.950	30.674	-2.421
D8	22.507	30.954	-3.342	17.355	34.151	-3.342	18.856	26.084	-2.400	14.522	28.706	-2.424
D9	27.151	27.151	-3.365	22.507	30.954	-3.342	22.773	22.894	-2.443	18.856	26.084	-2.400
D10	31.023	22.570	-3.359	27.151	27.151	-3.365	26.000	18.964	-2.419	22.772	22.894	-2.443
D11	34.178	17.494	-3.330	27.151	27.151	-3.365	28.705	14.673	-2.446	26.000	18.964	-2.419
D12	36.491	11.848	-3.357	34.178	17.494	-3.330	30.705	9.939	-2.454	28.705	14.673	-2.446
D13	37.943	6.033	-3.391	36.491	11.848	-3.357	31.879	5.040	-2.452	30.705	9.939	-2.454
D14	38.519	0.073	-3.411	37.943	6.033	-3.391	32.296	0.053	-2.476	31.879	5.040	-2.452
D15	38.141	-6.060	-3.462	38.519	0.073	-3.411	32.061	-5.164	-2.500	32.296	0.053	-2.476
D16	36.642	-11.938	-3.383	38.141	-6.060	-3.462	30.898	-10.066	-2.537	32.061	-5.164	-2.500
D17	34.171	-17.515	-3.403	36.642	-11.938	-3.383	28.929	-14.782	-2.509	30.898	-10.066	-2.537
D18	31.137	-22.549	-3.465	34.171	-17.515	-3.403	26.270	-19.039	-2.541	28.929	-14.782	-2.509
D21	27.330	-27.228	-3.477	31.137	-22.549	-3.465	23.031	-22.913	-2.548	26.270	-19.039	-2.541
D22	22.711	-31.138	-3.508	27.330	-27.228	-3.477	19.105	-26.238	-2.524	23.031	-22.913	-2.548
D23	17.570	-34.389	-3.436	22.711	-31.138	-3.508	14.839	-28.862	-2.444	19.105	-26.238	-2.524
D24	11.979	-36.611	-3.459	17.570	-34.389	-3.436	10.067	-30.902	-2.464	14.839	-28.862	-2.444
D25	6.132	-38.031	-3.387	11.979	-36.611	-3.459	5.128	-32.092	-2.463	10.067	-30.902	-2.464
D26	0.056	-38.485	-3.390	6.132	-38.031	-3.387	0.037	-32.518	-2.449	5.128	-32.092	-2.463
D27	-5.944	-38.078	-3.397	0.056	-38.485	-3.390	-5.060	-32.269	-2.454	0.037	-32.518	-2.449
D28	-11.877	-36.873	-3.429	-5.944	-38.078	-3.397	-9.996	-30.993	-2.414	-5.060	-32.269	-2.454
D29	-17.637	-34.855	-3.398	-11.877	-36.873	-3.429	-14.657	-28.937	-2.433	-9.996	-30.993	-2.414

Table B4. (Continued)

Ring Row D	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
D30	-22.546	-31.237	-3.371	-17.637	-34.855	-3.398	-19.005	-26.283	-2.428	-14.657	-28.937	-2.433
D31	-27.047	-27.221	-3.344	-22.546	-31.237	-3.371	-22.820	-22.972	-2.424	-19.005	-26.283	-2.428
D32	-30.961	-22.645	-3.380	-27.047	-27.221	-3.344	-26.208	-19.156	-2.448	-22.820	-22.972	-2.424
D33	-34.157	-17.547	-3.347	-30.961	-22.645	-3.380	-28.880	-14.823	-2.418	-26.208	-19.156	-2.448
D34	-36.382	-11.957	-3.365	-34.157	-17.547	-3.347	-30.860	-10.118	-2.434	-28.880	-14.823	-2.418
D35	-37.836	-6.144	-3.400	-36.382	-11.957	-3.365	-32.095	-5.206	-2.460	-30.860	-10.118	-2.434
D36	-38.489	-0.114	-3.401	-37.836	-6.144	-3.400	-32.334	-0.114	-2.412	-32.095	-5.206	-2.460
D37	-37.908	5.877	-3.338	-38.489	-0.114	-3.401	-32.029	4.924	-2.438	-32.334	-0.114	-2.412
D38	-36.575	11.773	-3.304	-37.908	5.877	-3.338	-30.910	9.934	-2.427	-32.029	4.924	-2.438
D39	-34.220	17.299	-3.287	-36.575	11.773	-3.304	-28.874	14.544	-2.417	-30.910	9.934	-2.427
D40	-30.971	22.403	-3.320	-34.220	17.299	-3.287	-26.261	18.980	-2.440	-28.874	14.544	-2.417
D41	-27.173	27.035	-3.297	-30.971	22.403	-3.320	-23.017	22.892	-2.458	-26.261	18.980	-2.440
D42	-22.612	30.975	-3.308	-27.173	27.035	-3.297	-19.139	26.222	-2.430	-23.017	22.892	-2.458

Table B5. RTK-GNSS Survey Data for Ring Row E.

Ring Row E	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
E1	-6.735	31.419	-2.467	-12.156	29.918	-2.444	-5.604	26.443	-1.649	-10.174	25.048	-1.671
E2	-1.174	32.087	-2.460	-6.735	31.419	-2.467	-0.988	26.957	-1.653	-5.604	26.443	-1.649
E3	4.482	32.010	-2.450	-1.174	32.087	-2.460	3.742	26.753	-1.640	-0.988	26.957	-1.653
E4	9.835	30.700	-2.420	4.482	32.010	-2.450	8.325	25.726	-1.638	3.742	26.753	-1.640
E5	15.071	28.377	-2.419	9.835	30.700	-2.420	12.694	23.855	-1.642	8.325	25.726	-1.638
E6	19.774	25.346	-2.426	15.071	28.377	-2.419	16.639	21.286	-1.654	12.694	23.855	-1.642
E7	23.944	21.564	-2.435	19.774	25.346	-2.426	20.115	18.045	-1.667	16.639	21.286	-1.654
E8	27.240	17.034	-2.458	23.944	21.564	-2.435	22.952	14.344	-1.648	20.115	18.045	-1.667
E9	29.848	12.053	-2.450	27.240	17.034	-2.458	25.079	10.120	-1.652	22.952	14.344	-1.648
E10	31.515	6.696	-2.459	29.848	12.053	-2.450	26.389	5.598	-1.656	25.079	10.120	-1.652
E11	32.187	1.114	-2.485	31.515	6.696	-2.459	27.000	0.867	-1.671	26.389	5.598	-1.656
E12	32.106	-4.508	-2.502	32.187	1.114	-2.485	26.786	-3.810	-1.732	27.000	0.867	-1.671
E13	30.884	-10.072	-2.518	32.106	-4.508	-2.502	25.707	-8.406	-1.703	26.786	-3.810	-1.732
E14	28.698	-15.260	-2.521	30.884	-10.072	-2.518	23.857	-12.688	-1.699	25.707	-8.406	-1.703
E15	25.493	-19.935	-2.542	28.698	-15.260	-2.521	21.315	-16.600	-1.709	23.857	-12.688	-1.699
E16	21.724	-24.067	-2.532	25.493	-19.935	-2.542	18.102	-20.168	-1.713	21.315	-16.600	-1.709
E17	17.157	-27.435	-2.487	21.724	-24.067	-2.532	14.380	-22.934	-1.717	18.102	-20.168	-1.713
E18	12.123	-30.039	-2.457	17.157	-27.435	-2.487	10.127	-25.157	-1.725	14.380	-22.934	-1.717
E19	6.767	-31.707	-2.478	12.123	-30.039	-2.457	5.648	-26.534	-1.688	10.127	-25.157	-1.725
E20	1.158	-32.417	-2.460	6.767	-31.707	-2.478	0.903	-27.008	-1.672	5.648	-26.534	-1.688
E21	-4.507	-32.299	-2.458	1.158	-32.417	-2.460	-3.733	-26.825	-1.708	0.903	-27.008	-1.672
E22	-10.047	-30.960	-2.432	-4.507	-32.299	-2.458	-8.391	-25.760	-1.709	-3.733	-26.825	-1.708
E23	-15.158	-28.630	-2.442	-10.047	-30.960	-2.432	-12.681	-23.934	-1.729	-8.391	-25.760	-1.709
E24	-19.862	-25.512	-2.436	-15.158	-28.630	-2.442	-16.629	-21.356	-1.681	-12.681	-23.934	-1.729

Table B5 (Continued)

Ring Row E	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
E25	-23.980	-21.730	-2.407	-19.862	-25.512	-2.436	-20.103	-18.133	-1.708	-16.629	-21.356	-1.681
E26	-27.435	-17.144	-2.425	-23.980	-21.730	-2.407	-22.929	-14.388	-1.650	-20.103	-18.133	-1.708
E27	-29.989	-12.176	-2.417	-27.435	-17.144	-2.425	-25.063	-10.215	-1.668	-22.929	-14.388	-1.650
E28	-31.703	-6.804	-2.441	-29.989	-12.176	-2.417	-26.466	-5.702	-1.684	-25.063	-10.215	-1.668
E29	-32.243	-1.189	-2.394	-31.703	-6.804	-2.441	-27.008	-1.029	-1.694	-26.466	-5.702	-1.684
E30	-32.061	4.438	-2.425	-32.243	-1.189	-2.394	-26.810	3.718	-1.676	-27.008	-1.029	-1.694
E31	-30.901	9.925	-2.426	-32.061	4.438	-2.425	-25.720	8.284	-1.657	-26.810	3.718	-1.676
E32	-28.561	15.140	-2.429	-30.901	9.925	-2.426	-23.895	12.681	-1.667	-25.720	8.284	-1.657
E33	-25.536	19.860	-2.476	-28.561	15.140	-2.429	-21.305	16.588	-1.655	-23.895	12.681	-1.667
E34	-21.711	24.011	-2.454	-25.536	19.860	-2.476	-18.121	20.065	-1.684	-21.305	16.588	-1.655
E35	-17.236	27.463	-2.439	-21.711	24.011	-2.454	-14.343	22.865	-1.658	-18.121	20.065	-1.684
E36	-12.156	29.918	-2.444	-17.236	27.463	-2.439	-10.174	25.048	-1.671	-14.343	22.865	-1.658

Table B6. RTK-GNSS Survey Data for Ring Row F.

Ring Row F	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
F1	-1.379	26.898	-1.658	-7.002	26.006	-1.649	-1.127	21.591	-1.070	-5.598	20.873	-1.070
F2	4.248	26.649	-1.632	-1.379	26.898	-1.658	3.386	21.343	-1.068	-1.127	21.591	-1.070
F3	9.679	25.125	-1.669	4.248	26.649	-1.632	7.804	20.189	-1.101	3.386	21.343	-1.068
F4	14.666	22.582	-1.667	9.679	25.125	-1.669	11.820	18.138	-1.086	7.804	20.189	-1.101
F5	19.066	19.012	-1.652	14.666	22.582	-1.667	15.343	15.308	-1.100	11.820	18.138	-1.086
F6	22.666	14.718	-1.654	19.066	19.012	-1.652	18.189	11.803	-1.089	15.343	15.308	-1.100
F7	25.237	9.622	-1.656	22.666	14.718	-1.654	20.215	7.688	-1.102	18.189	11.803	-1.089
F8	26.594	4.203	-1.661	25.237	9.622	-1.656	21.358	3.376	-1.086	20.215	7.688	-1.102
F9	26.850	-1.483	-1.707	26.594	4.203	-1.661	21.655	-1.170	-1.139	21.358	3.376	-1.086
F10	25.980	-7.073	-1.715	26.850	-1.483	-1.707	20.910	-5.671	-1.150	21.655	-1.170	-1.139
F11	23.999	-12.335	-1.709	25.980	-7.073	-1.715	19.232	-9.926	-1.167	20.910	-5.671	-1.150
F12	20.964	-17.109	-1.737	23.999	-12.335	-1.709	16.757	-13.671	-1.130	19.232	-9.926	-1.167
F13	16.976	-20.983	-1.706	20.964	-17.109	-1.737	13.523	-16.727	-1.104	16.757	-13.671	-1.130
F14	12.226	-24.053	-1.715	16.976	-20.983	-1.706	9.844	-19.300	-1.134	13.523	-16.727	-1.104
F15	6.981	-26.110	-1.686	12.226	-24.053	-1.715	5.602	-20.939	-1.081	9.844	-19.300	-1.134
F16	1.414	-26.940	-1.667	6.981	-26.110	-1.686	1.181	-21.606	-1.076	5.602	-20.939	-1.081
F17	-4.215	-26.704	-1.702	1.414	-26.940	-1.667	-3.387	-21.372	-1.091	1.181	-21.606	-1.076
F18	-9.659	-25.231	-1.709	-4.215	-26.704	-1.702	-7.705	-20.180	-1.089	-3.387	-21.372	-1.091
F19	-14.688	-22.620	-1.688	-9.659	-25.231	-1.709	-11.794	-18.144	-1.110	-7.705	-20.180	-1.089
F19_dup	-19.042	-19.102	-1.703	-14.688	-22.620	-1.688	-15.294	-15.385	-1.139	-11.794	-18.144	-1.110
F21	-22.668	-14.726	-1.669	-19.042	-19.102	-1.703	-18.136	-11.818	-1.104	-15.294	-15.385	-1.139
F22	-25.200	-9.723	-1.681	-22.668	-14.726	-1.669	-20.220	-7.784	-1.115	-18.136	-11.818	-1.104
F23	-26.641	-4.251	-1.677	-25.200	-9.723	-1.681	-21.377	-3.423	-1.126	-20.220	-7.784	-1.115
F24	-26.901	1.364	-1.683	-26.641	-4.251	-1.677	-21.630	1.054	-1.110	-21.377	-3.423	-1.126

Table B6. (Continued)

Ring Row F	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
F25	-26.047	6.965	-1.664	-26.901	1.364	-1.683	-20.928	5.614	-1.105	-21.630	1.054	-1.110
F26	-24.067	12.237	-1.671	-26.047	6.965	-1.664	-19.275	9.789	-1.106	-20.928	5.614	-1.105
F27	-20.955	16.988	-1.653	-24.067	12.237	-1.671	-16.789	13.583	-1.090	-19.275	9.789	-1.106
F28	-16.966	20.892	-1.689	-20.955	16.988	-1.653	-13.615	16.787	-1.079	-16.789	13.583	-1.090
F29	-12.191	23.973	-1.659	-16.966	20.892	-1.689	-9.811	19.277	-1.076	-13.615	16.787	-1.079
F30	-7.002	26.006	-1.649	-12.191	23.973	-1.659	-5.598	20.873	-1.070	-9.811	19.277	-1.076

Table B7. RTK-GNSS Survey Data for Ring Row G.

Ring Row G	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
G1	-6.653	20.504	-1.048	-11.722	18.019	-1.075	-5.074	15.655	-0.592	-8.938	13.829	-0.590
G2	-1.139	21.613	-1.062	-6.653	20.504	-1.048	-0.852	16.414	-0.590	-5.074	15.655	-0.592
G3	4.521	21.085	-1.070	-1.139	21.613	-1.062	3.453	16.083	-0.589	-0.852	16.414	-0.590
G4	9.789	19.203	-1.103	4.521	21.085	-1.070	7.482	14.674	-0.588	3.453	16.083	-0.589
G5	14.480	16.035	-1.081	9.789	19.203	-1.103	11.037	12.249	-0.634	7.482	14.674	-0.588
G6	18.175	11.825	-1.074	14.480	16.035	-1.081	13.825	8.974	-0.620	11.037	12.249	-0.634
G7	20.515	6.646	-1.089	18.175	11.825	-1.074	15.665	5.090	-0.636	13.825	8.974	-0.620
G8	21.526	1.127	-1.107	20.515	6.646	-1.089	16.409	0.908	-0.617	15.665	5.090	-0.636
G9	21.109	-4.513	-1.114	21.526	1.127	-1.107	16.119	-3.416	-0.628	16.409	0.908	-0.617
G10	19.264	-9.848	-1.153	21.109	-4.513	-1.114	14.667	-7.530	-0.634	16.119	-3.416	-0.628
G11	16.100	-14.499	-1.095	19.264	-9.848	-1.153	12.235	-10.937	-0.626	14.667	-7.530	-0.634
G12	11.821	-18.171	-1.095	16.100	-14.499	-1.095	8.888	-13.680	-0.630	12.235	-10.937	-0.626
G19	6.679	-20.518	-1.090	11.821	-18.171	-1.095	5.119	-15.659	-0.624	8.888	-13.680	-0.630
G20	1.170	-21.597	-1.074	6.679	-20.518	-1.090	0.910	-16.421	-0.618	5.119	-15.659	-0.624
G21	-4.492	-21.085	-1.095	1.170	-21.597	-1.074	-3.405	-16.121	-0.639	0.910	-16.421	-0.618
G22	-9.737	-19.225	-1.090	-4.492	-21.085	-1.095	-7.419	-14.693	-0.628	-3.405	-16.121	-0.639
G23	-14.459	-16.080	-1.127	-9.737	-19.225	-1.090	-10.987	-12.242	-0.597	-7.419	-14.693	-0.628
G24	-18.114	-11.815	-1.111	-14.459	-16.080	-1.127	-13.750	-8.988	-0.598	-10.987	-12.242	-0.597
G25	-20.505	-6.689	-1.099	-18.114	-11.815	-1.111	-15.625	-5.085	-0.617	-13.750	-8.988	-0.598
G26	-21.515	-1.180	-1.123	-20.505	-6.689	-1.099	-16.427	-0.888	-0.633	-15.625	-5.085	-0.617
G27	-21.085	4.482	-1.122	-21.515	-1.180	-1.123	-16.096	3.424	-0.590	-16.427	-0.888	-0.633
G28	-19.246	9.797	-1.108	-21.085	4.482	-1.122	-14.623	7.426	-0.584	-16.096	3.424	-0.590
G29	-15.976	14.384	-1.100	-19.246	9.797	-1.108	-12.233	11.034	-0.571	-14.623	7.426	-0.584
G30	-11.722	18.019	-1.075	-15.976	14.384	-1.100	-8.938	13.829	-0.590	-12.233	11.034	-0.571

Table B8. RTK-GNSS Survey Data for Ring Row H.

Ring Row H	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
H1	-7.446	14.602	-0.601	-11.591	11.579	-0.573	-5.602	11.033	-0.354	-8.745	8.696	-0.312
H2	-2.517	16.120	-0.588	-7.446	14.602	-0.601	-1.895	12.023	-0.374	-5.602	11.033	-0.354
H3	2.556	16.147	-0.583	-2.517	16.120	-0.588	1.916	11.908	-0.374	-1.895	12.023	-0.374
H4	7.478	14.680	-0.577	2.556	16.147	-0.583	5.502	10.727	-0.335	1.916	11.908	-0.374
H5	11.614	11.587	-0.646	7.478	14.680	-0.577	8.718	8.660	-0.354	5.502	10.727	-0.335
H6	14.599	7.421	-0.622	11.614	11.587	-0.646	10.958	5.602	-0.377	8.718	8.660	-0.354
H7	16.084	2.552	-0.638	14.599	7.421	-0.622	12.125	1.909	-0.373	10.958	5.602	-0.377
H8	16.170	-2.526	-0.614	16.084	2.552	-0.638	12.036	-1.933	-0.386	12.125	1.909	-0.373
H9	14.675	-7.499	-0.628	16.170	-2.526	-0.614	10.845	-5.549	-0.380	12.036	-1.933	-0.386
H10	11.698	-11.666	-0.635	14.675	-7.499	-0.628	8.770	-8.686	-0.369	10.845	-5.549	-0.380
H11	7.515	-14.688	-0.631	11.698	-11.666	-0.635	5.654	-11.088	-0.361	8.770	-8.686	-0.369
H12	2.565	-16.118	-0.619	7.515	-14.688	-0.631	1.974	-12.087	-0.327	5.654	-11.088	-0.361
H13	-2.542	-16.193	-0.639	2.565	-16.118	-0.619	-1.885	-11.983	-0.339	1.974	-12.087	-0.327
H14	-7.445	-14.677	-0.619	-2.542	-16.193	-0.639	-5.487	-10.827	-0.346	-1.885	-11.983	-0.339
H15	-11.516	-11.589	-0.590	-7.445	-14.677	-0.619	-8.654	-8.678	-0.352	-5.487	-10.827	-0.346
H16	-14.535	-7.434	-0.609	-11.516	-11.589	-0.590	-10.970	-5.631	-0.343	-8.654	-8.678	-0.352
H17	-16.104	-2.595	-0.643	-14.535	-7.434	-0.609	-12.000	-1.890	-0.368	-10.970	-5.631	-0.343
H18	-16.155	2.533	-0.588	-16.104	-2.595	-0.643	-11.971	1.897	-0.354	-12.000	-1.890	-0.368
H19	-14.605	7.462	-0.586	-16.155	2.533	-0.588	-10.833	5.509	-0.326	-11.971	1.897	-0.354
H20	-11.591	11.579	-0.573	-14.605	7.462	-0.586	-8.745	8.696	-0.312	-10.833	5.509	-0.326

Table B9. RTK-GNSS Survey Data for Ring Row I.

Ring Row I	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
I1	-5.394	11.182	-0.366	-9.206	8.300	-0.307	-3.719	7.744	-0.179	-6.374	5.773	-0.169
I2	-0.721	12.312	-0.410	-5.394	11.182	-0.366	-0.442	8.564	-0.185	-3.719	7.744	-0.179
I3	4.069	11.530	-0.356	-0.721	12.312	-0.410	2.861	8.065	-0.185	-0.442	8.564	-0.185
I4	8.294	9.198	-0.373	4.069	11.530	-0.356	5.753	6.334	-0.188	2.861	8.065	-0.185
I5	11.189	5.289	-0.372	8.294	9.198	-0.373	7.720	3.689	-0.205	5.753	6.334	-0.188
I6	12.418	0.690	-0.378	11.189	5.289	-0.372	8.552	0.435	-0.207	7.720	3.689	-0.205
I7	11.693	-4.132	-0.388	12.418	0.690	-0.378	8.064	-2.846	-0.205	8.552	0.435	-0.207
I8	9.222	-8.268	-0.371	11.693	-4.132	-0.388	6.374	-5.704	-0.191	8.064	-2.846	-0.205
I9	5.397	-11.274	-0.374	9.222	-8.268	-0.371	3.719	-7.654	-0.197	6.374	-5.704	-0.191
I10	0.721	-12.392	-0.327	5.397	-11.274	-0.374	0.436	-8.533	-0.178	3.719	-7.654	-0.197
I11	-4.062	-11.680	-0.340	0.721	-12.392	-0.327	-2.803	-8.064	-0.190	0.436	-8.533	-0.178
I12	-8.223	-9.228	-0.371	-4.062	-11.680	-0.340	-5.695	-6.376	-0.180	-2.803	-8.064	-0.190
I13	-11.196	-5.370	-0.355	-8.223	-9.228	-0.371	-7.736	-3.773	-0.186	-5.695	-6.376	-0.180
I14	-12.323	-0.672	-0.372	-11.196	-5.370	-0.355	-8.605	-0.478	-0.190	-7.736	-3.773	-0.186
I15	-11.594	4.149	-0.340	-12.323	-0.672	-0.372	-8.167	2.847	-0.193	-8.605	-0.478	-0.190
I16	-9.206	8.300	-0.307	-11.594	4.149	-0.340	-6.374	5.773	-0.169	-8.167	2.847	-0.193

Table B10. RTK-GNSS Survey Data for Ring Row J.

Ring Row J	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
J1	0.457	8.712	-0.192	-3.120	8.119	-0.183	0.345	6.002	-0.077	-2.140	5.566	-0.072
J2	3.950	7.738	-0.202	0.457	8.712	-0.192	2.690	5.317	-0.074	0.345	6.002	-0.077
J3	6.780	5.493	-0.206	3.950	7.738	-0.202	4.640	3.723	-0.078	2.690	5.317	-0.074
J4	8.450	2.253	-0.197	6.780	5.493	-0.206	5.710	1.555	-0.092	4.640	3.723	-0.078
J5	8.634	-1.343	-0.216	8.450	2.253	-0.197	5.830	-0.919	-0.088	5.710	1.555	-0.092
J7	7.335	-4.750	-0.216	8.634	-1.343	-0.216	4.983	-3.217	-0.084	5.830	-0.919	-0.088
J8	4.772	-7.249	-0.223	7.335	-4.750	-0.216	3.254	-4.954	-0.054	4.983	-3.217	-0.084
J9	1.394	-8.562	-0.157	4.772	-7.249	-0.223	0.946	-5.790	-0.071	3.254	-4.954	-0.054
J10	-2.199	-8.355	-0.191	1.394	-8.562	-0.157	-1.467	-5.682	-0.093	0.946	-5.790	-0.071
J11	-5.370	-6.703	-0.192	-2.199	-8.355	-0.191	-3.677	-4.581	-0.082	-1.467	-5.682	-0.093
J12	-7.666	-3.972	-0.196	-5.370	-6.703	-0.192	-5.176	-2.697	-0.071	-3.677	-4.581	-0.082
J13	-8.607	-0.461	-0.193	-7.666	-3.972	-0.196	-5.866	-0.335	-0.088	-5.176	-2.697	-0.071
J14	-8.128	3.098	-0.186	-8.607	-0.461	-0.193	-5.527	2.053	-0.082	-5.866	-0.335	-0.088
J15	-6.122	6.129	-0.176	-8.128	3.098	-0.186	-4.181	4.175	-0.072	-5.527	2.053	-0.082
J16	-3.120	8.119	-0.183	-6.122	6.129	-0.176	-2.140	5.566	-0.072	-4.181	4.175	-0.072

Table B11. RTK-GNSS Survey Data for Ring Row K.

Ring Row K	Bottom of Ring Row						Top of Ring Row					
	Left			Right			Left			Right		
	x	y	z	x	y	z	x	y	z	x	y	z
K1	-2.281	5.517	-0.077	-4.476	3.943	-0.074	-1.481	3.498	-0.023	-2.950	2.388	-0.024
K2	0.333	5.974	-0.073	-2.281	5.517	-0.077	0.131	3.811	-0.025	-1.481	3.498	-0.023
K3	2.941	5.251	-0.085	0.333	5.974	-0.073	1.902	3.296	-0.035	0.131	3.811	-0.025
K4	4.915	3.464	-0.081	2.941	5.251	-0.085	3.122	2.274	-0.061	1.902	3.296	-0.035
K5	5.943	0.979	-0.088	4.915	3.464	-0.081	3.821	0.616	-0.062	3.122	2.274	-0.061
K6	5.786	-1.669	-0.088	5.943	0.979	-0.088	3.711	-0.982	-0.056	3.821	0.616	-0.062
K7	4.489	-4.062	-0.080	5.786	-1.669	-0.088	2.826	-2.618	-0.036	3.711	-0.982	-0.056
K8	2.380	-5.545	-0.078	4.489	-4.062	-0.080	1.621	-3.514	-0.038	2.826	-2.618	-0.036
K9	-0.330	-5.996	-0.072	2.380	-5.545	-0.078	-0.199	-3.905	-0.027	1.621	-3.514	-0.038
K10	-2.858	-5.274	-0.090	-0.330	-5.996	-0.072	-1.776	-3.456	-0.031	-0.199	-3.905	-0.027
K11	-4.833	-3.464	-0.070	-2.858	-5.274	-0.090	-3.092	-2.271	-0.034	-1.776	-3.456	-0.031
K12	-5.897	-1.089	-0.083	-4.833	-3.464	-0.070	-3.718	-0.874	-0.035	-3.092	-2.271	-0.034
K13	-5.756	1.620	-0.077	-5.897	-1.089	-0.083	-3.672	0.961	-0.031	-3.718	-0.874	-0.035
K14	-4.476	3.943	-0.074	-5.756	1.620	-0.077	-2.950	2.388	-0.024	-3.672	0.961	-0.031